NOTICE

All drawings located at the end of the document.

RF/RMRS-98-234.UN

Final Report to the Source Evaluation and Mitigating Actions Plan for Walnut Creek

April, 1998

U.S. Department of Energy

Rocky Flats Environmental Technology Site

Golden, Colorado

BZ-A-000445

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FIGURES

TABLES

LIST OF ACRONYMS

30dAvg	thirty day average
AMS	Actinide Migration Studies
Am	americium
APO	Analytical Projects Office
b	probability of Ho testing false when actually true
cfs	cubic feet per second
CDPHE	Colorado Department of Public Health and the Environment
Ci/g	curies per gram
D&D	decontamination and decommissioning
DQO	data quality objectives
EMD	Environmental Management Division
EPA	the Environmental Protection Agency

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ER	environmental restoration
GS (or SW)	gaging stations
gal	gallon
g/cm^3	grams per cubic centimeter
GPS	Global Positioning System
IHSS	individual hazardous substance site
IMP	Integrated Monitoring Plan
L	semimajor axis length
mg/l	milligram/liter
mm	millimeter
N	number of samples
NSQ	non-sufficient quantity
pCi/g	pico-Curies/gram
pCi/l	pico-Curies/liter
POC	Point of Compliance
POE	Point of Evaluation
Pu	plutonium
PuO_2	plutonium oxide
RFCA	Rocky Flats Cleanup Agreement
RFETS	Rocky Flats Environmental Technology Site
RMRS	Rocky Mountain Remediation Services, L.L.C.
S	elliptical axes length
SOW	Statement of Work
SNM	special nuclear material
TSS	total suspended solids
U	uranium
WEPP	Watershed Erosion Prediction Procedure
WWTP	Wastewater Treatment Plant
WY	Water Year

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1. EXECUTIVE SUMMARY

Rocky Flats Environmental Technology Site personnel have completed the initial investigation into, and are continuing the source evaluation of, the cause(s) of exceedances of 30-day moving averages for plutonium (Pu) and americium (Am) water-quality standards at the Walnut Creek Rocky Flats Cleanup Agreement (RFCA) Point of Compliance (POC) monitoring location, GS03 and two upstream Point of Evaluation (POE) monitoring locations, GS10, and SW093. First reported on August 15, 1997 the exceedances may be summarized as:

- Elevated 30-day moving average values were measured at the POC monitoring location at Walnut Creek and Indiana Street (referred to as GS03) for the period June 12 through July 2, 1997;
- Elevated 30-day moving averages values were also measured at the POE monitoring location above Pond B-1 (referred to as GS10) for the periods April 13 through April 24, 1997, May 25 through June 20, 1997, August 2 through September 3, 1997, and September 22 through October 21, 1997; and
- Elevated values were observed at the POE monitoring location above Pond A-1 (referred to as SW093) for the period August 2, 1997 through August 3, 1997.

RFCA requires reporting of "exceedances in Segment 5" and when "standards are exceeded at a Point of Compliance (POC)." In such events, RFCA further requires a "source evaluation and mitigating action." This Final Report is the last of four scheduled Source Evaluation Reports established by the *Final Source Evaluation and Mitigating Action Plan* and scheduled for completion by April 15, 1998.[1]

Site personnel consider the elevated water-quality measurements at the Site's boundary POC GS03 (and upstream Walnut Creek basin POEs) in the past year to be a serious problem While the public health risk related to this exceedance is negligible, elevated values such as these have not previously been measured at the Site boundary and the significance for the future remediation of the Site could be great. Site personnel are continuing a surface-water source investigation using both in-house and outside expertise, as well as state-of-the-art research methods and technologies. Enhancements in monitoring activities and administrative processes have been implemented to provide early indications and improved resolution of any future water-quality excursions, and to continue to investigate the cause of elevated Pu levels at GS03 (in 1997) and at upstream evaluation locations.

Site personnel have completed an extensive evaluation of historical data; collected additional field soil, sediment, and water samples for analyses; and assessed Site activities and monitoring programs. To date, no localized areas of radiological contamination have been identified—either historical or resulting from current operations – that could have caused this exceedance. Site personnel have thus concluded that the

[1] Data are still outstanding at the completion of this Report. Specifically, soil sampling results (see Section 4.2), soil particle-size fractionation information, and other Actinide Migration Studies results are not available. This information and analysis will be made available in Actinide Migration Studies reports and either RFCA Quarterly Reports or Quarterly State Exchange Meetings.

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likely source of the exceedances of the 30-day average for Pu and Am, in particular at Point of Compliance GS03, was diffuse radionuclide contamination from past Site operations released to the environment through events and conditions over past years. Sensitivity analyses on the available monitoring data also indicate that the GS03 exceedance was strongly influenced by a single, elevated sample result which was collected during unseasonably low-flow conditions. The source evaluation has uncovered no information to indicate that recent Site activities are responsible. Based on the evaluation to this point, Site personnel believe that no specific remedial action(s) is indicated at this time as the source investigations have identified no localized source(s) of contamination.

This Final Report contains no specific recommendations for source control due to the exceedance that was measured at GS03. The recommended course of action in this report will not compromise protection of human health and the environment since: (1) the plutonium and americium released from the Site which caused the exceedance, aggregated with the volume-weighted activity for the Water Year, is well below the annualized mass loading used to develop the POC Standard value of 0.15 pCi/l Pu and Am, and (2) there is no consumptive use of the RFETS water that is discharged due to Option B changes in Walnut Creek.[2]

It should be noted that the recommendations of this report do not supplant the regulatory agencies' authority to compel corrective actions when necessary to protect human health and the environment. Nor do the recommendations impair or impede Site implementation of mitigation activities should new sources be identified or if additional exceedances would warrant corrective actions.

Several generic remedial actions might be considered to minimize or prevent future exceedances. For example, Site personnel could either remove contaminated soils or capture and remove contaminants at the Site boundary. Specifically, Site personnel have considered the following options:

- Remove all above-background plutonium-contaminated soils and sediments that could contribute to an exceedance. This approach cannot be done without major adverse ecological impacts and considerable expense.

- Construct large dams immediately upstream of Indiana Street on both Walnut and Woman Creeks and treat the water collected, as necessary, prior to release to prevent exceedances. This approach would also be expensive and present major ecological issues, even though it might not be 100% effective in the event of large storms.

The Site's proposed course of action includes (1) continuing observation (routine monitoring and special sampling, as appropriate of the surface water), and (2) continuing progress on the actinide migration study. Key to understanding water quality variation on site, this multi-disciplinary study and the associated watershed modeling initiative will eventually describe the extent to which, and conditions under which

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[2] Implementation of Option B in Walnut Creek included the purchase of a new water supply and construction of a new water treatment facility for Broomfield.

plutonium and americium move in the Rocky Flats environs. Site personnel expect that these efforts will eventually provide insights about the cause(s) and possible prevention of radionuclide water-quality exceedances. Effective best management practices, such as the use of the existing terminal ponds to clarify stormwater of potentially contaminated sediment and particulate matter, should be continued.

Several questions continue to be evaluated or are awaiting closure relative to understanding water-quality issues in the Walnut Creek basin:

- Can source control effectively control water quality and prevent future exceedances?
- Are small, isolated contaminant particles a factor in, or the cause of, exceedances?
- Are detection limits and low-activity analytical measurements a factor in exceedances?
- Are changed sampling techniques and practices a factor in the exceedances?
- Will pending Walnut Creek basin soil testing and watershed modeling reveal some heretofore unrecognized problem areas in the basin?

Because the diffuse sources of Pu and Am appear to be wide-spread and the Pu and Am standards of 0.15 pCi/l are so low, it is probable that there will be future exceedances. This likely and, at this point, unpreventable situation may: (1) draw repetitive enforcement actions with no benefit to the water quality; (2) provide a continuing source of public and political stress; and (3) drain the Site's cleanup resources. Given the likelihood of fu6ture exceedances, the lack of risk to human health and the environment as a result thereof, and the disadvantages of the corrective actions identified to date, the report recommends that Site personnel, Regulators, and Stakeholders consider a broader perspective or alternative compliance strategy and either:

- adopt an equivalent annual mass-loading standard to replace the current concentration-based standard in RFCA, though contrary to the state's water-quality practices, to provide a more realistic measure of potential off-site impacts in the absence of direct domestic use, or
- revise the Pu and Am standards applicable to Rocky Flats to reflect an actual risk basis or current actual and projected water use, though this presents some public policy and political challenges especially with regard to the newly adopted state-wide standards for Pu and Am.

The Site proposes the following actions as part of the path forward:

1. Continue observation (routine monitoring and special sampling, as appropriate to the evaluation) and ongoing data interpretation to provide understanding of actinide transport directly related to the operation of the Site automated surface-water monitoring network;

2. Continue progress on the Actinide Migration Studies (AMS) as a longer-term technical study to provide understanding of transuranic migration to eventually provide insights about the cause(s) and possible prevention of radionuclide water-quality exceedances;

3. Continue use of the existing detention ponds to clarify stormwater of potentially contaminated sediment and particulate matter as an effective best management practice;

4. Incorporate direct and increased stakeholder participation through the formation of a Surface-Water Issues Working Group as outlined in Appendix 5 of RFCA; and,

5. Provide progress reporting through AMS reports, Quarterly RFCA Reports, Quarterly State Exchange Meetings, and informal status / flash briefs.

2. INTRODUCTION

This source evaluation report is provided in accordance with the Final Rocky Flats Cleanup Agreement (RFCA) (Attachment 5, §2.4(B)) under "Action Determinations". The RFCA requires reporting of "exceedances in Segment 5" and when "standards are exceeded at a POC" and that a "source evaluation and mitigating action will be required". Specifically, this source evaluation addresses the August 15, 1997 Rocky Flats Environmental Technology Site (Site) report of elevated 30-day moving averages for plutonium (Pu) and americium (Am) water-quality results in Walnut Creek. These elevated values were measured at the POC monitoring location at Walnut Creek and Indiana Street (referred to as GS03) for the period June 12 through July 2,1997. Elevated values were also measured at the POE monitoring location above Pond B-1 (referred to as GS10) for the periods April 13 through April 24,1997, May 25 through June 20, 1997, August 2 through September 3, 1997, and September 22 through October 21, 1997. Finally, elevated values were observed at the POE monitoring location above Pond A-1 (referred to as SW093) for the period August 2, 1997 through August 3,1997. This Final Report is the fourth in a series the Site has committed to completing as outlined in Source Evaluation and Preliminary Proposed Mitigating Actions for Walnut Creek Water-Quality Results, September 1997 (Revision 2; RF/RMRS-97-081.UN). This Plan was delivered to the Colorado Department of Public Health and the Environment (CDPHE), the Environmental Protection Agency (EPA), the City of Broomfield and the City of Westminster, on September 15, 1997. The gaging stations of interest are shown on Figure 2-1.

In order to allow sufficient time for effective source evaluation while simultaneously providing the more frequent dissemination of information and results as they become available, a series of three Source Evaluation Progress Reports, and a Final Source Evaluation and Mitigating Actions Plan have been completed. The Progress Reports have been produced at intervals during the source evaluation process as specific actions are completed. During the production of each deliverable, additional information has been collected which was included in subsequent reports as available. The Reports are presented in Table 2-1.

Table 2-1. Schedule of Deliverables.

Deliverable	Completion Date
Source Evaluation Progress Report #1	September 30, 1997; Completed
Source Evaluation Progress Report #2	November 17, 1997; Completed
Source Evaluation Progress Report #3	December 31, 1997; Completed
Final Source Evaluation Report and Mitigating Actions Plan	April 15, 1998

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Source evaluations require analysis of constituent fate, transport, and loading, as well as statistical analysis and the establishment of water-quality correlations which may indicate the location of a contaminant source. To date, no discrete source of surface-water contamination has been identified and quantified in Walnut Creek. This lack of an identified discrete source makes the application of effective mitigating actions impossible at this time. The Site has committed to increase the scope of routine RFCA surface-water monitoring to identify source areas should water-quality exceedances occur in the future. This Final Report describes the progress of source evaluation actions for Walnut Creek gaging stations GS03, GS10, and SW093 and covers data received by March 25, 1998. This Final Report includes the ongoing assessment of monitoring data for GS03, GS10, and SW093. The following is included in this Final Report for Walnut Creek:

- Updates to the ongoing GS03, GS10, and SW093 evaluations;
- Results and analysis of ongoing RFCA monitoring;
- An assessment and incorporation of available new data for GS03, GS10, and SW093;
- Updates for the new Source Location monitoring stations[3] for GS03, GS10, and SW093;
- Hypotheses for source location(s) with supporting and non-supporting information;
- An identification of data gaps and uncertainties in the source evaluation process with suggested modifications (if any) to the AMS Workscope and the IMP;
- A summary of current AMS findings with cross-links to source evaluations;
- A summary of the status for sampling and operational modifications;
- Results of the source location evaluation;
- A detailed description of identified source areas; and
- A general description of mitigating actions applicable to sources which may be identified in the future.

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[3] Source Location monitoring stations are automated gaging stations installed as part of a source evaluation under RFCA. These locations are installed according to the Integrated Monitoring Plan (IMP) Source Location decision rule and current Site automated surface-water monitoring practices. Operation of these gages is tailored to meet the requirements of each source evaluation.

3. BACKGROUND

3.1. SITE HYDROLOGY

Walnut Creek, the subject of this investigation and one of several Site drainages, flows east past the Site's boundary at Indiana Street (Figure 3-1). Surface-water monitoring station GS03 is located on Walnut Creek approximately 100 yards west of Indiana Street. Downstream of Indiana Street, flows are diverted around Great Western Reservoir via the Broomfield Diversion Ditch, and back to Walnut Creek. Walnut Creek eventually flows into Big Dry Creek (at Hwy 36 and Church Ranch Blvd.), and on to the South Platte River.

Walnut Creek Tributaries

Upstream from station GS03, Walnut Creek receives flow from the following four tributaries (listed in order from north to south and shown in Figure 3-1):

- McKay Bypass Canal (Coal Creek water conveyance canal);
- No Name Gulch (buffer zone drainage basin east of the Landfill Pond);
- North Walnut Creek (northern Industrial Area drainage basin); and
- South Walnut Creek (central Industrial Area drainage basin).

No Name Gulch and the McKay Bypass Canal typically flow only during the spring or following large storm events, receive runoff from non-Industrial Area drainage basins, and are not controlled by detention ponds. The McKay Bypass is also used by Broomfield to transfer water from Coal Creek to Great Western Reservoir. Both North and South Walnut Creek, in contrast, have nearly continuous baseflow, receive runoff from the Industrial Area, and are controlled by a system of detention ponds. A discussion follows describing how water runs off the Industrial Area, into North and South Walnut Creeks, through the detention pond network, and, ultimately, into Walnut Creek where it continues to station GS03.

North and South Walnut Creek Flow Controls

All Industrial Area surface-water runoff that flows into North or South Walnut Creek is collected in a system of Site detention ponds. The ponds serve three main purposes for surface-water management: (1) stormwater detention and settling of sediments, (2) water storage for sampling and, if necessary, settling prior to release, and (3) emergency spill control in those instances where a spill cannot be adequately managed without use of the ponds.

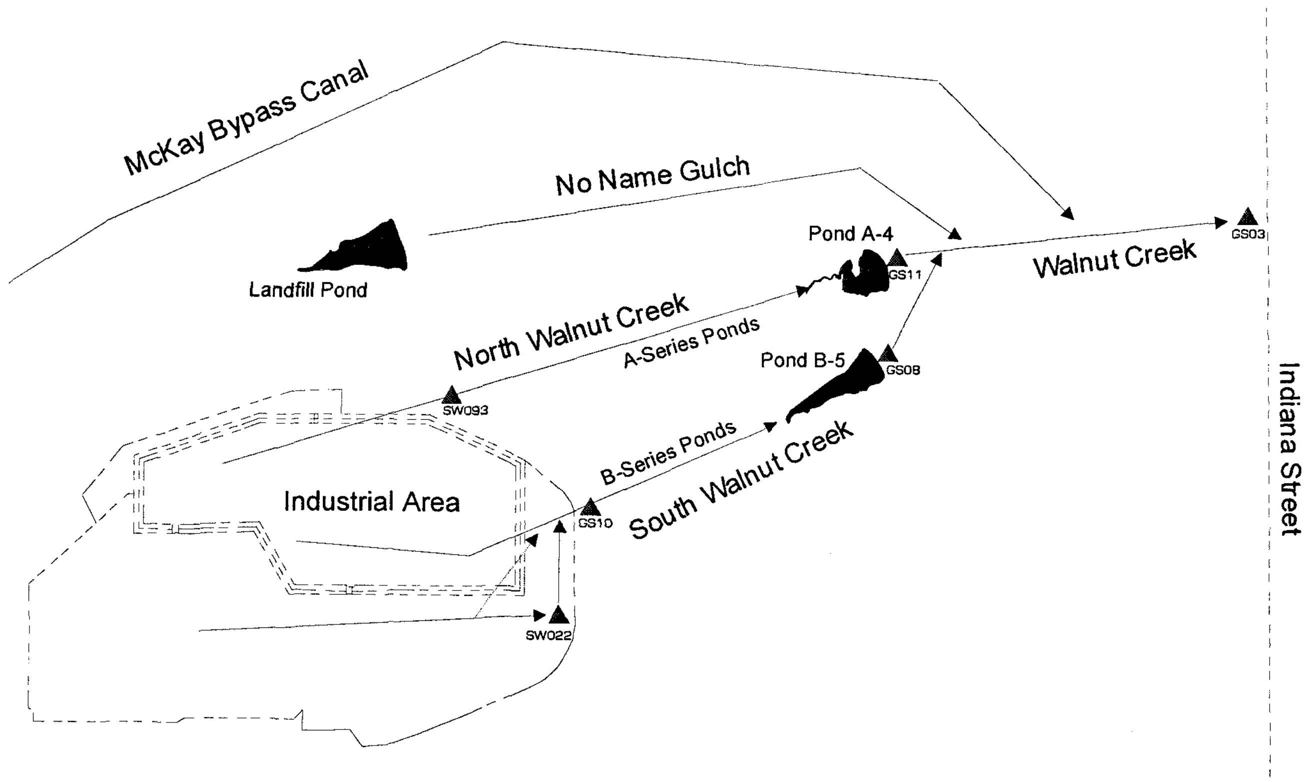

Figure 3-1. Hydrologic Connectivity of Site Drainage and Water Management Features.

North Walnut Creek water is routed through the A-Series ponds (Figure 3-1). Steps in the water collection and transfer process are summarized as follows:

- Runoff from the northern Industrial Area flows directly to SW093;
- Runoff from SW093 flows downstream into Pond A-3;
- Water is held in Pond A-3, then periodically (≈ 9 times per year) released in batches into Pond A-4; and
- After Pond A-4 is filled to about 50% of capacity, flows into Pond A-4 (from Pond A-3) are discontinued, thereby isolating the A-4 water from the rest of the pond network. A sample of the A-4 water is collected and analyzed by CDPHE, and if sample results indicate water quality standards are met, the "batch" of water is discharged through the outlet works of Pond A-4. Samples are collected of the Pond A-4 discharge water, at station GS11, and the water flows on to Walnut Creek and station GS03. These batch releases from Pond A-4 occur from 6 to 12 times per year, depending on the amount of precipitation received at the Site, and involve approximately 100 to 200 million gallons of water annually.

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South Walnut Creek water is routed through the latter B-Series ponds. Steps in the normal water collection and transfer process are briefly outlined as follows:

- Runoff from the south-central Industrial Area flows through the Central Avenue Ditch to SW022, and then to GS10 (during high runoff periods, some water in the Central Avenue Ditch overflows to a large corrugated metal pipe and flows directly to GS10; shown by dotted line in Figure 3-1);
- Runoff from the central Industrial Area flows directly to GS10;
- Runoff from GS10 then flows downstream through conveyance structures to Pond B-4 and on to Pond B-5 where it is held; and
- The Site plans to periodically batch discharge water held in Pond B-5 to Walnut Creek in a manner similar to that used for Pond A-4.[4]

As indicated above, all of the Industrial Area runoff that flows into North and South Walnut Creeks is ultimately routed through Ponds A-4 and B-5, detained, and routinely sampled prior to being released to Walnut Creek. There is no source of runoff from the Industrial Area that can enter Walnut Creek without first passing through the pond system and then be discharged from these two terminal ponds. Downstream from the terminal ponds, the only sources of surface-water entering Walnut Creek upstream of GS03 are No Name Gulch, the McKay Bypass Canal, or overland runoff directly into Walnut Creek.

3.2. GS03 MONITORING RESULTS

As specified in the IMP, the Site evaluates 30-day moving averages[5] for selected radionuclides at RFCA POEs and POCs. Continuous flow-paced sampling is conducted at all RFCA POEs and POCs using automated flow-measurement and sampling equipment[6,7]. This section presents recent evaluations of water-

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[4] The Pond B-5 outlet works were upgraded in March 1998. Prior to the completion of the B-5 outlet works upgrades, water detained in Pond B-5 was pumped periodically in batches to Pond A-4. This water was then isolated from inflows while awaiting subsequent batch discharge. This discharge scenario for B-5 may be implemented in the future.

[5] The 30-day average for a particular day is calculated as a volume-weighted average of a 'window' of time containing the previous 30-days which had flow. Each day has its own discharge volume (measured at the location with a flow meter) and activity (from the sample carboy in place that day). Therefore, there are 365 30-day moving averages for a location which flows all year. At locations which monitor pond discharges or have intermittent flows, 30-day averages are reported as averages of the previous 30 days of greater than zero flow. For days where no activity is available, either due to failed lab analysis or NSQ for analysis, no 30-day average is reported. See footnote 12 for a discussion of NSQ.

[6] Through the use of the Data Quality Objectives (DQO) process, the IMP specifies the target number of composite samples ('carboys' receiving multiple grabs) to be collected at each monitoring location. The IMP further specifies that

quality measurements at POC surface-water monitoring location GS03 (see Figure 2-1) which showed values above the POC Standard value of 0.15 pCi/l Pu and Am. GS03 is located on Walnut Creek west of Indiana Street. Results for 30-day moving averages using available data at GS03 are summarized below in Table 3-1 and are also plotted in Figure 3-2.[8] The mean daily flow rate and available individual sample results are plotted in Figure 3-3.

Table 3-1. Water-Quality Information from GS03: October 1, 1996 through December 4, 1997.

Location	Parameter	Date(s) 30-Day Average Above 0.15 pCi/l	Date(s) of Maximum 30-Day Average	Maximum 30-Day Average (pCi/l)	Volume Weighted Average for Period (pCi/l)
GS03	Pu-239,240	6/12/97 - 7/2/97	6/13/97 - 6/24/97	0.465	0.024
GS03	Am-241	6/13/97 - 6/24/97	6/13/97 - 6/24/97	0.256	0.014

For reference, the 30-day Pu average at GS03 was between 0.05 pCi/l and 0.15 pCi/l for the following periods: April 16 through 26, 1997; June 10 through 11, 1997; July 3 through 5, 1997; and August 5 through 26, 1997.

Table 3-1 shows the volume-weighted average activities for the entire period of RFCA monitoring (10/1/96 through 12/4/97)[9]. Additionally, Table 3-2 shows the volume-weighted average activities for WY97 and WY98. Although the exceedance at GS03 occurred in WY97, it is important to note that the annual volume-weighted average Pu activity for WY97 is 0.032 pCi/l. Additionally, if the sample result from May 15, 1997 through June 25, 1997 (0.465 pCi/l Pu; 0.256 pCi/l Am) is excluded from the calculation of 30-day volume-

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these carboys should be flow-paced. The flow pacing is based on the predicted stream discharge using historical record for each location. For example (for a specific location), if two carboys are targeted for a certain month, and the historical discharge volume is 100,000 gallons, then each carboy should represent 50,000 gallons. Grab samples of 200 ml are collected; smaller grabs push the repeatability limits of the auto-sampler. Since the carboys can hold 15 L, and the minimum volume for analysis is ≈ 5 L; the samplers are programmed to place 10 L (50 grabs) in the carboy. So, for 50,000 gallons, the sampler is programmed for 1 grab per 1,000 gallons (50,000 gals/50 grabs). Targeting 50 grabs allows for periods of discharge greater than expected (up to 75 grabs) without having to collect additional carboys. Similarly, periods of discharge less that expected (25 grabs) may still yield enough sample for analysis.

[7] Automated sampling protocols at POEs and POCs were changed to a continuous flow-paced protocol on October 1, 1996 with the implementation of RFCA monitoring.

[8] Gaps in the 30-day average for GS03 are a result of an NSQ event. For days where no activity is available due to an NSQ condition, no 30-day average is reported. See footnote 12 for a discussion of NSQ.

[9] The composite sample started on 12/5/97 was collected on February 12, 1998. Results have not been returned from the laboratories.

weighted moving averages, then no exceedances occur. Since it is likely that the transport of actinides in surface water is influenced by other environmental parameters which vary seasonally, these values may be more representative of longer-term variations in surface-water radionuclide activities at GS03.

Table 3-2. Volume-Weighted Average Activities at GS03: Water Years[10] 1997-1998.

Period	Parameter	Volume Weighted Average for Period (pCi/l)
WY97	Pu-239,240	0.032
	Am-241	0.017
WY98[a]	Pu-239,240	0.004
	Am-241	0.007

[a] Covers the period from 10/1/97 through 12/4/97.

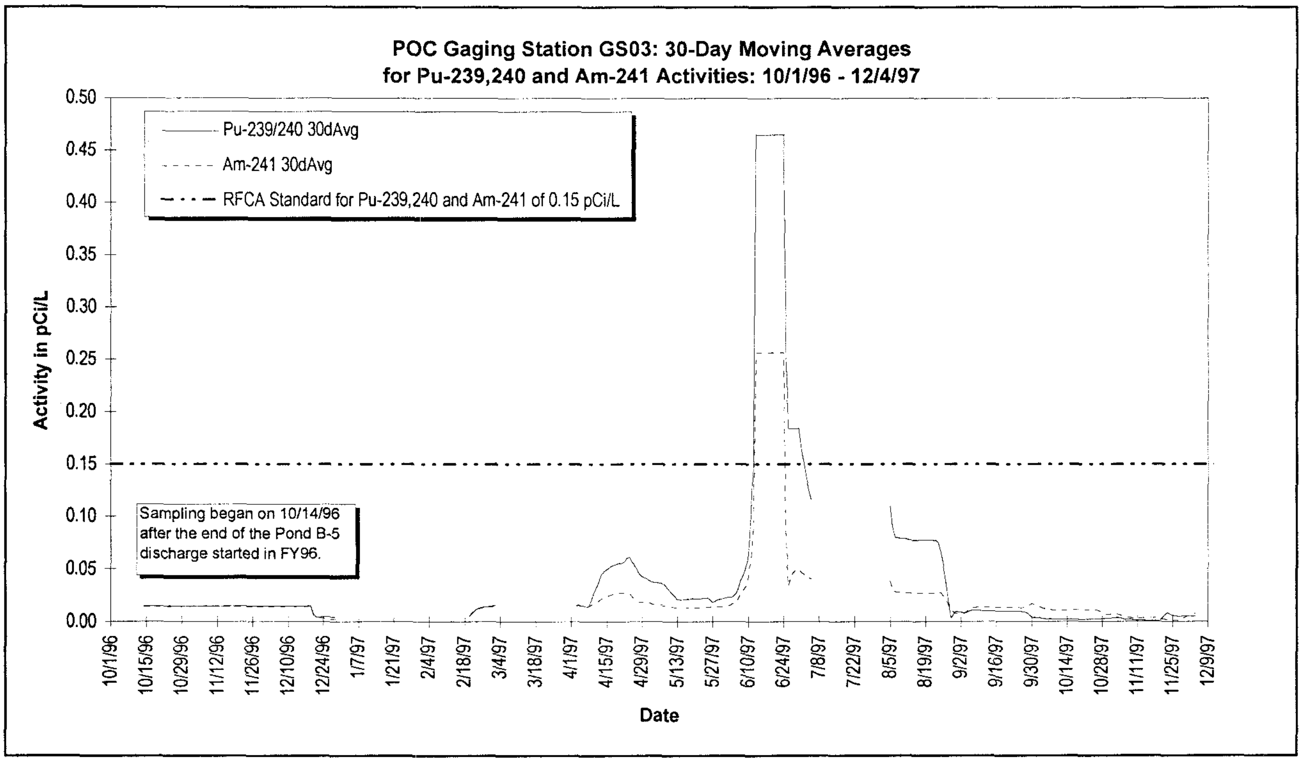
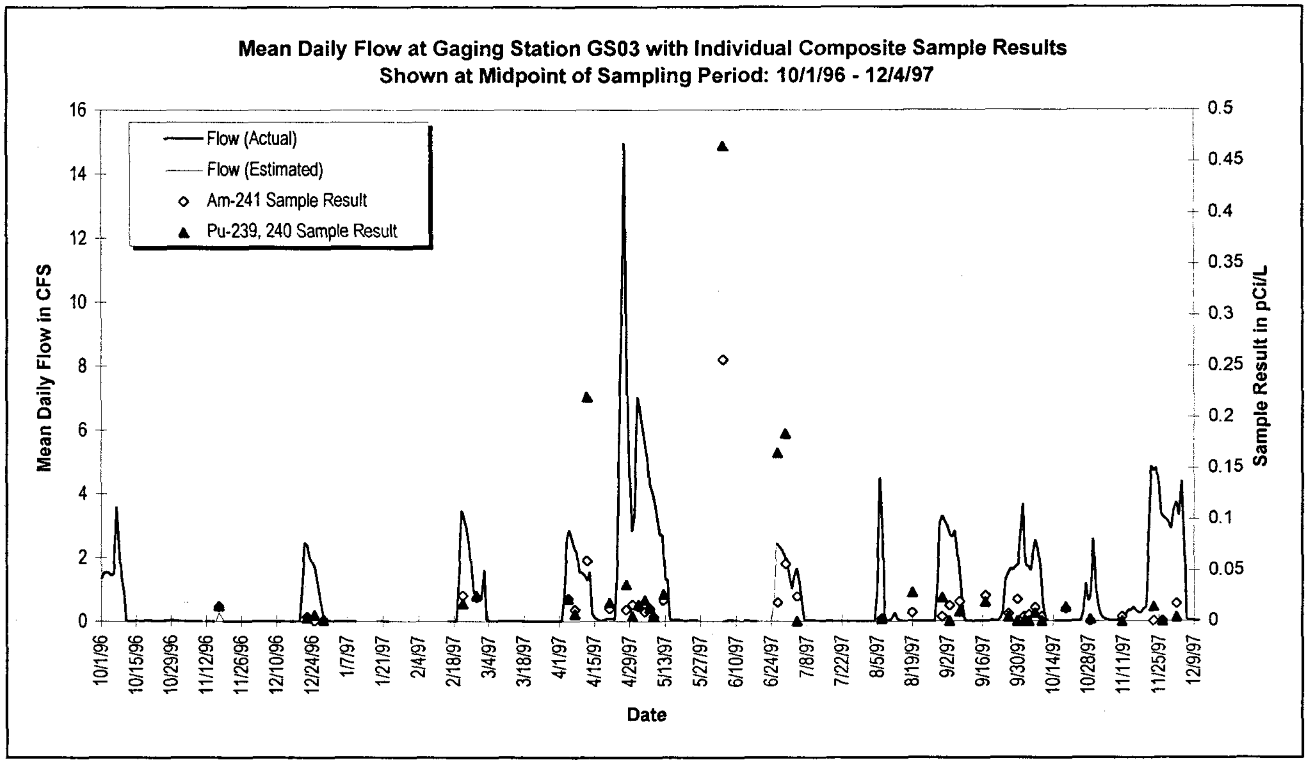


Figure 3-2. Gaging Station GS03 30-Day Averages: October 1, 1996 through December 4, 1997.

[10] A water year (abbreviated as WY) is defined as the period October 1 through September 30.



Intermittent peaks represent periodic discharges from terminal ponds A-4 and B-5; runoff peak (≈ 4/24-4/28/97) is from large snowmelt event. Sampling began on 10/14/96 after the completion of a B-5 discharge. Sample values shown where data has been received from analytical labs (10/1/96 - 12/4/97).

Figure 3-3. Gaging Station GS03 Hydrograph and Sample Results.

The individual analytical results for the composite samples collected around the period of these elevated 30-day averages have been carefully reviewed for accuracy. Based on past analytical results for this location, these elevated values are considered unusual, with historical measurements[11] being well below 0.05 pCi/l. Samples collected after the period of elevated measurements showed normal Pu and Am activities. Individual composite sample results and details are shown in Table 3-3 for the periods of interest.

[11] Historical values are available in the Site Annual Environmental Reports and the Quarterly Environmental Monitoring Reports.

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Table 3-3. Selected Composite Sample Analytical Results for GS03.

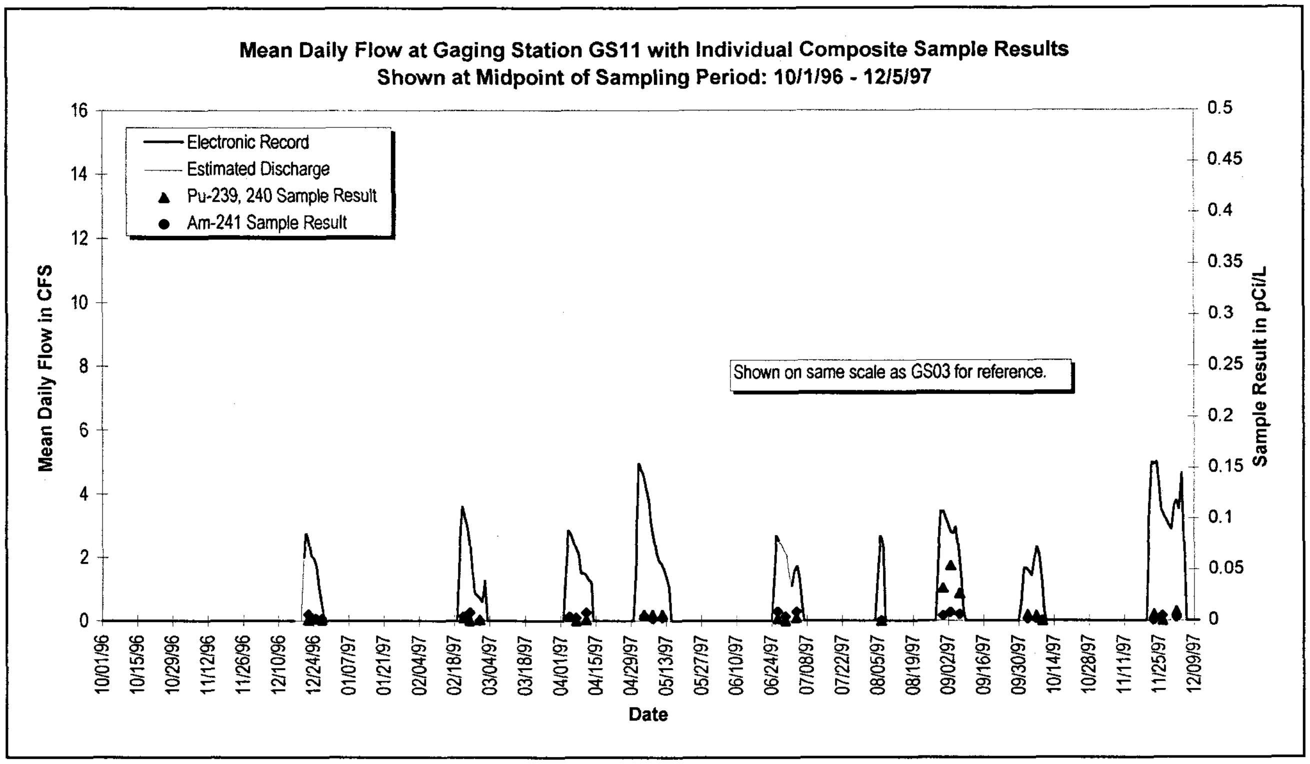
Composite Sample Period	Pu-239,240 (pCi/l)		Am-241 (pCi/l)		Composite Sample Volume (Liters)	Walnut Cr. Discharge Volume During Sample Period (Million Gallons)
	Result	Error	Result	Error		
4/8 - 4/13/97	**0.220**	**±0.045**	**0.059**	**±0.064**	**1.2[a]**	**5.31**
5/15 -6/25/97[b]	**0.465**	**±0.129**	**0.256**	**±0.116**	**1.0**	**0.34**
6/25 - 6/27/97	**0.165[c]**	**±0.052**	**0.018**	**±0.021**	**8.0**	**2.83**
6/27 - 7/1/97	**0.184**	**±0.046**	**0.056**	**±0.036**	**8.6**	**5.37**
7/1 - 7/6/97	0.000[d]	±0.006	0.024	±0.022	8.4	4.11
8/5 - 8/8/97[e]	0.002	±0.011	0.002	±0.023	17.4	5.42
8/8 - 8/29/97	0.028	±0.000	0.008	±0.008	6.8	0.35
8/29 - 9/1/97	0.023	±0.004	0.004	±0.007	8.8	5.69

[a] Low sample volume (1.2 liter) due to frozen sampler lines; this sample did not give a 30-day Pu average above 0.15 pCi/l.
[b] Low sample volume (1 liter) due to unseasonably dry weather and associated low flows.
[c] This is an arithmetic average for values of the first analytical run (0.206 pCi/l) and a rerun (0.124 pCi/l); error is an arithmetic average.
[d] Actual result was -0.004 pCi/l for this sample; result was set to zero for practical reporting and calculation purposes. Negative values result from background correction whereby activities for laboratory blanks and corrections for counterefficiencies are used to compute the analytical results.
[e] During the period from 7/6/97 - 8/5/97, the sampler collected an insufficient quantity for analysis due to unseasonably low flow rates.
The Site contractually required detection limit for Pu and Am in water is 0.03 pCi/l.

The composite sample at GS03 for the period May 15, 1997 through June 25, 1997 was collected during low-flow conditions between Pond A-4 (the terminal pond for North Walnut Creek) discharges. It should be noted that this produced a low-volume sample (NSQ[12]), relative to radio-analytical protocols which recommend a minimum sample volume of 4 liters to produce accurate results. The two composite samples at GS03 for the period June 25, 1997 through July 1, 1997 were collected as the first 2-of-3 composites during a Pond A-4 discharge (See Table A-1 for Summary of Pond Discharges). Analytical results for composite samples from POC gaging station GS11 (location shown on Figure 2-1), which monitors controlled discharges from Pond A-4, showed no elevated readings for Pu-239,240 or Am-241 for the discharges which occurred during the period of elevated measurements at GS03. Table A-2 and Figure 3-4

[12] For situations where non-sufficient quantity (NSQ) is collected for analysis, either due to equipment failures or exceptionally low streamflows, the IMP specifies that the sample may be discarded. NSQ occurs occasionally for GS03 during low-flow or baseflow periods. At GS03, the IMP currently targets 1 carboy for the periods of baseflow between terminal pond discharges. The IMP further specifies that the carboy must represent only baseflow, and must be removed from the sampler at the beginning of a Terminal pond discharge. Therefore, if flows significantly less than predicted are measured at GS03, the flow-paced carboy may not receive sufficient volume for analysis before it must be removed from the sampler. Changes have been made to sampling protocols to reduce the risk of NSQ (See Program Status, Issues, and Highlights sections in previous reports).

summarize these results at GS11. Additionally, Pond B-5 discharges during this period showed normally low Pu and Am levels (as shown in Table A-3).



Samples shown where data has been received form analytical labs (10/1/96 - 12/5/97).

Figure 3-4. Gaging Station GS11 Hydrograph and Sample Results.

These results indicate that water discharged from the Site's terminal ponds is not the source of the elevated measurements at GS03. This information suggests that the source of the Pu and Am measured at GS03 is downstream of the terminal ponds or located in a tributary to Walnut Creek in the terminal pond-to-GS03 stream reach. This area has no known sources of significant contamination. For reference, Figure 3-1 shows the hydrologic routing for drainages and water management facilities which are related to GS03.

During the time period of elevated measurements at GS03, no off-normal conditions were noted in decontamination and decommissioning (D&D), special nuclear material (SNM) stabilization, or environmental restoration (ER) activities that may have affected water quality, nor were there any closure activities occurring in the Walnut Creek drainage between Pond A-4 and Indiana Street. An initial walk-down of the Walnut Creek drainage between GS03 and Pond A-4 was conducted on August 15, 1997 and revealed no unusual conditions which might provide insight into elevated radionuclides in surface water for the May-July timeframe. Subsequent walk-downs were also performed in No Name Gulch. Immediately downstream of station GS03 the water flowed off-Site and was diverted around Great Western Reservoir.

3.3. GS10 MONITORING RESULTS

As specified in the IMP, the Site evaluates 30-day moving averages (see footnote 5) for selected radionuclides and other parameters at gaging station GS10. GS10 receives flow from the central Industrial Area and monitors flow to South Walnut Creek via the B-1 bypass pipeline to Pond B-4 which flows into Pond B-5. Recent evaluations of water-quality measurements at POE surface-water monitoring location GS10 (located on South Walnut Creek just above Pond B-1 as shown on Figure 2-1) show values above 0.15 pCi/l for Pu and Am. Results for 30-day moving averages using available sample results at GS10 are summarized below in Table 3-4 and are shown on Figure 3-5.

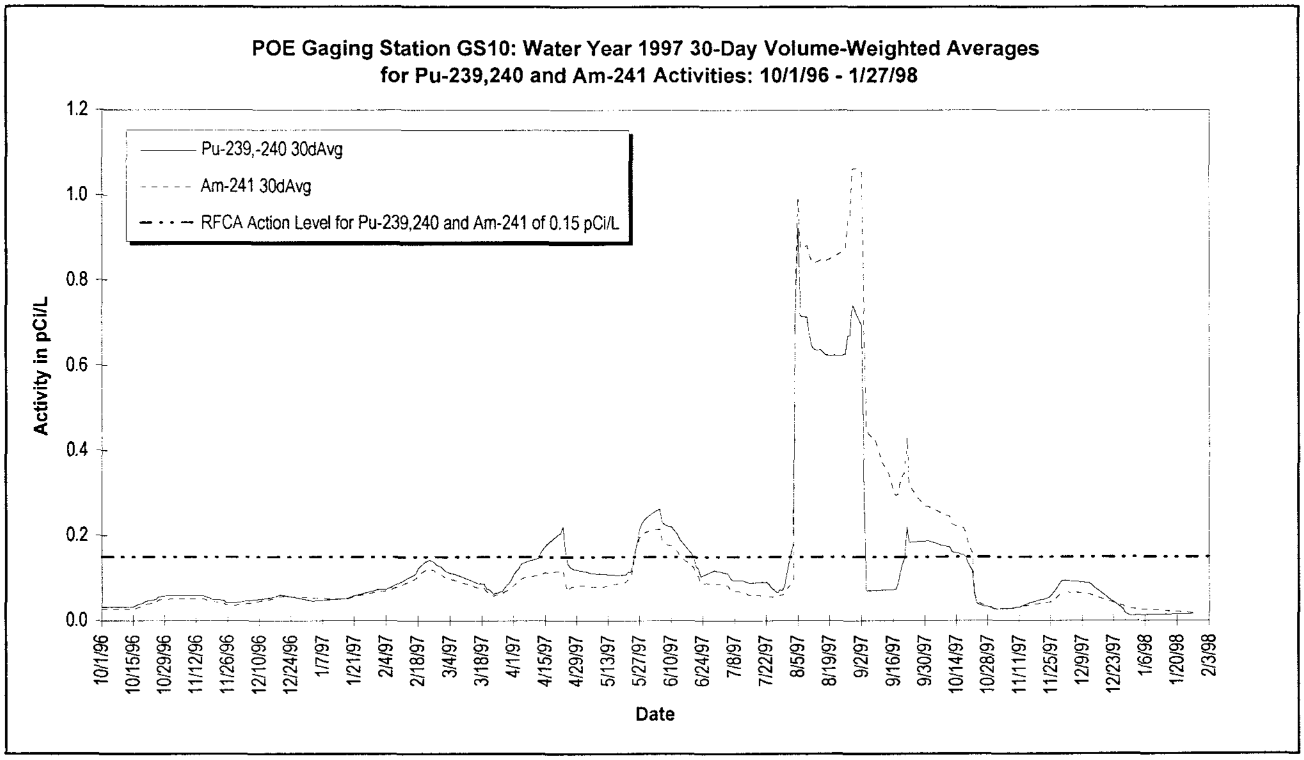


Figure 3-5. Gaging Station GS10 30-Day Averages: October 1, 1996 through January 27, 1998.

For reference, the 30-day Pu average at GS10 was between 0.05 pCi/l and 0.15 pCi/l for the following periods: October 26 through November 18, 1996; December 11 through 29, 1996; January 14 through April 12, 1997; April 25 through May 24, 1997; June 21 through August 1, 1997; September 4 through 21, 1997; October 18 through 22, 1997; and November 22 through December 21, 1997.

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Table 3-4. Water-Quality Information from GS10: October 1, 1996 through January 27, 1998.

Location	Parameter	Date(s) 30-Day Average Above 0.15 pCi/l	Date(s) of Maximum 30-Day Average	Maximum 30-Day Average (pCi/l)	Volume Weighted Average for Period (pCi/l)
GS10	Pu-239,240	4/13/97 - 4/24/97 5/25/97 - 6/20/97 8/2/97 - 9/3/97 9/22/97 - 10/17/97	8/5/97	0.921	0.191
GS10	Am-241	5/25/97 - 6/14/97 8/4/97 - 10/21/97	8/31/97	1.063	0.229

[a] Samples shown where data has been received from analytical labs (10/1/96 - 1/27/98).

Table 3-5. Volume-Weighted Average Activities at GS10: Water Years 1997-1998.

Period	Parameter	Volume Weighted Average for Period (pCi/l)
WY97	Pu-239,240	0.237
	Am-241	0.287
WY98[a]	Pu-239,240	0.039
	Am-241	0.036

[a] Covers the period from 10/1/97 through 1/27/98.

Table 3-4 shows the volume-weighted average activities for the entire period of RFCA monitoring (10/1/96 through 1/27/98). Additionally, Table 3-5 shows the volume-weighted average activities for WY97 and WY98. Since it is likely that the transport of actinides in surface water is influenced by other environmental parameters which vary seasonally, these values may be more representative of longer term variations in surface-water radionuclide activities at GS10.

The analytical results for the composite samples collected around the period have been verified. A review of historical monitoring data shows that these results are not unusual. Storm-event[13] samples collected at GS10 from 1992 through 1996 (under pre-RFCA protocols) had an arithmetic average Pu-239,240 activity of 0.23 pCi/l with a maximum of 1.4 pCi/l. The apparent upward trend during Water Year 1997 is likely due to seasonally increasing flow rates which carry increased suspended material. The significant increase

[13] Storm-event samples are generally flow-paced composites consisting of 15 grabs taken during a direct runoff hydrograph. The grabs are targeted to be taken on the rising limb of the direct runoff hydrograph. The rising limb is defined as the period of time when the flow rates at a location are increasing in response to runoff from a precipitation or snowmelt event.

in activity during the first week of August 1997 likely occurred due to intense runoff events associated with summer monsoon weather patterns.

All water monitored at GS10 during this period flowed to Pond B-5 and was transferred to Pond A-4 for subsequent discharge or direct discharged from B-5 to Walnut Creek. Pre-discharge samples of the water in Ponds A-4 and B-5 indicated acceptable water quality for all discharges. Analytical results from composite samples collected at gaging stations GS11 (Pond A-4 outfall) and GS08 (Pond B-5 outfall), during each discharge, were well below the RFCA standard (see Table A-2 and Table A-3). This improvement in water-quality between pond influent (runoff from the Industrial Area to the Ponds) and effluent (water discharged from the terminal ponds) indicates that the Site's water-management practices help to reduce migration of contamination. Individual composite sample results and detail for GS10 are shown in Table A-4 around the period during exceedances.

3.4. SW093 MONITORING RESULTS

As specified in the IMP, the Site evaluates 30-day moving averages(see footnote 5) for selected radionuclides and other parameters at gaging station SW093. SW093 receives flow from the northern and central Industrial Area and monitors flow to North Walnut Creek which then enters the A-1 bypass pipeline to Pond A-3 which is batch discharged into Pond A-4. Recent evaluations of water-quality measurements at POE surface-water monitoring location SW093 (located on North Walnut Creek above Pond A-1 as shown on Figure 2-1) show values above 0.15 pCi/l for Pu. Results for 30-day moving averages using available data at SW093 are summarized below in Table 3-6 and shown on Figure 3-6.

A review of historical monitoring data shows that these results are not unusual. Storm-event samples collected at SW093 from WY92 through WY96 (under pre-RFCA protocols) had an arithmetic average Pu-239,240 activity of 0.73 pCi/l with a maximum of 5.3 pCi/l. The apparent upward trend during WY97 is likely due to seasonally increasing flow rates which carry increased suspended material. The significant increase in activity during the first week of August 1997 likely occurred due to intense runoff events associated with summer monsoon weather patterns. To the best of the Site's knowledge, no off-normal conditions were reported or experienced at any D&D, SNM stabilization, or ER activities during this time period that could have produced these water-quality measurements.

Table 3-6. Water-Quality Information from SW093: October 1, 1996 through January 27, 1998.

Location	Parameter	Date(s) 30-Day Average Above 0.15 pCi/l	Date(s) of Maximum 30-Day Average	Maximum 30-Day Average (pCi/l)	Volume Weighted Average for Period (pCi/l)
SW093	Pu-239,240	8/2 - 8/3/97	8/3/97	0.181	0.028

[a] Samples shown where data has been received from analytical labs (10/1/96 through 1/27/98).

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For reference, the 30-day Pu average at SW093 was between 0.05 pCi/l and 0.15 pCi/l for the following periods: October 1, 1996 through January 9, 1997; April 25, 1997; July 26 through August 1, 1997; and August 4 through 31, 1997.

Table 3-7. Volume-Weighted Average Activities at SW093: Water Years 1997-1998.

Period	Parameter	Volume Weighted Average for Period (pCi/l)
WY97	Pu-239,240	0.039
	Am-241	0.022
WY98[a]	Pu-239,240	0.003
	Am-241	0.006

[a] Covers the period from 10/1/97 through 1/27/98.

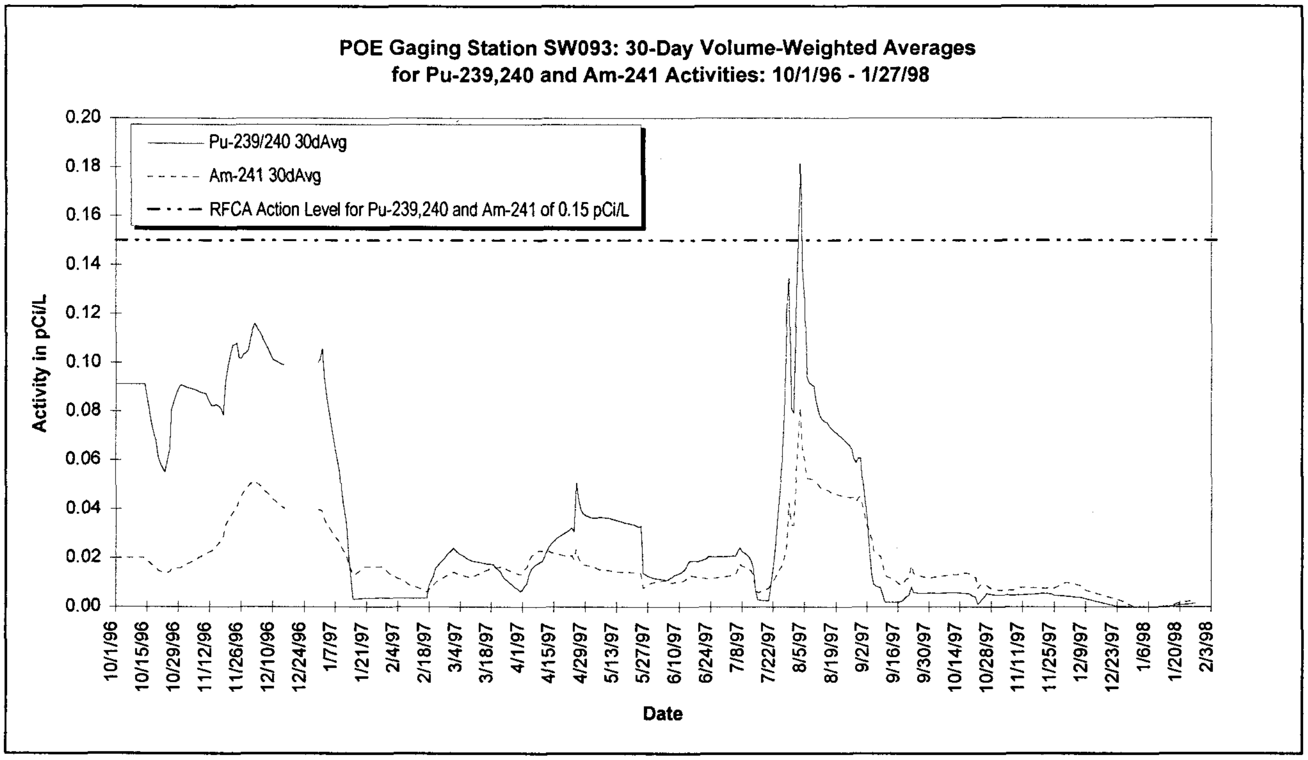

Figure 3-6. Gaging Station SW093 30-Day Averages: October 1, 1996 through January 27, 1998.

Table 3-6 shows the volume-weighted average activities for the entire period of RFCA monitoring (10/1/96 through 1/27/98). Additionally, Table 3-7 shows the volume-weighted average activities for WY97 and WY98. Since it is likely that the transport of actinides in surface water is influenced by other environmental parameters which vary seasonally, these values may be more representative of longer term variations in surface-water radionuclide activities at SW093. It should also be noted that the exceedance at SW093 lasted only two days.

All water monitored at SW093 during this period subsequently flowed to Pond A-3, was batch discharged to Pond A-4, and was subsequently batch discharged to Walnut Creek. Pre-discharge samples of the water in Pond A-4 indicated acceptable water quality for all discharges. Analytical results from composite samples collected at gaging station GS11 (Pond A-4 outfall) during each discharge were well below the RFCA standard (see Table A-2). This improvement in water-quality between pond influent (runoff from the Industrial Area to the Ponds) and effluent (water discharged from the terminal ponds) indicates that the Site's water-management practices help to reduce migration of contamination. Individual composite sample results and detail for SW093 are shown in Table A-5 around the period of exceedance.

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4. DATA SUMMARY AND ANALYSIS FOR GS03

All Industrial Area runoff and Wastewater Treatment Plant (WWTP) effluent tributary to Walnut Creek pass through the terminal ponds A-4 and B-5. Since discharges from A-4 (GS11) showed no elevated activities during the period of elevated activities at GS03 (as discussed in Section 3.2), it is assumed that the source of the radionuclide activity at GS03 is downstream from the terminal ponds. Therefore, Progress Report #1 primarily included analysis and interpretation of environmental information for the GS03 drainage from the Site terminal ponds to Indiana Street, including tributaries. New information collected since Progress Reports #1, #2, and #3 is included in the following section. A cross-referenced discussion of this information and the specific source location hypotheses they support (or not) are included in Section 5.

4.1. AUTOMATED SURFACE-WATER MONITORING DATA

This section presents data summary and analysis for environmental information collected at gaging stations GS03 (Walnut Creek at Indiana Street) and upstream tributary locations GS08 (Pond B-5 outlet), GS11 (Pond A-4 outlet), GS33 (No Name Gulch at Walnut Cr.), GS34 (Walnut Cr. above McKay Ditch), and GS35 (McKay Ditch at Walnut Cr.) as shown in Figure 2-1. Data presented include flow rates, discharge volumes, radionuclide activities, radionuclide loads, and water-quality parameters. Analysis was performed on averages of all data available from WY93 to present, the continuous flow-paced samples from WY97, and the periods of WY98 that are available[14,15]. Although both Pu and Am were elevated at GS03, for simplicity and because of their close associations in RFETS environs, this section focuses on the transport and source location for Pu only.

4.1.1. Data Summary

Significant data exists for flow and radionuclide activities at the gaging stations of interest. Information for total suspended solids (TSS), metals, and major ions is limited. Additional information for these parameters may need to be collected if the progress of the ongoing source evaluation demonstrates the need for additional data to draw definite conclusions. Individual results are averages of target, duplicate, and replicate results for each sample. Results which were rejected through the validation process are not

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[14] Flow data is included for the period 10/1/92 - 2/28/98; analytical data is included for the period from 10/1/92 - 2/28/98, where available from the labs.

[15] Continuous flow-paced samples are collected continually during all flow regimes (direct runoff and baseflows) to obtain a sample result which is representative of the overall water quality. Conversely, rising limb and periodic grab (i.e. monthly grab samples) samples are representative of only the period of time during which they were collected. Therefore, direct comparisons of the results from differing sampling protocols assumes that the results from rising limb and periodic grab protocols are also representative of the water which was not sampled during intervening periods.

included. All activities are for total radionuclides and negative results were set to zero for calculation purposes.

Surface-Water Flow Rates and Discharge Volumes

Reliable flow records have been collected at GS03, GS08, and GS11 since WY93. Discharge record collection at Source Location stations GS33, GS34, and GS35 began on September 17, 1997, February 5, 1998, and September 19, 1997, respectively[16]. Site terminal pond discharges to Walnut Creek represent an average of 63% of the volume annually measured at GS03. However, this average is highly influenced by the very high runoff volumes in WY95. For WY93, WY94, WY96, WY97, and WY98, the terminal pond discharges represent 95% of the volume measured at GS03. Variation of flow rates and discharge volumes is significant in Walnut Creek, and coincides with variation in precipitation (as shown on Figure 4-1 and Figure 4-2). Significant gains in flow rates are seen at GS03 for the spring months as overland flow occurs in the drainage between the terminal ponds and GS03. Additionally, tributaries and seeps contribute relatively more water during these months.

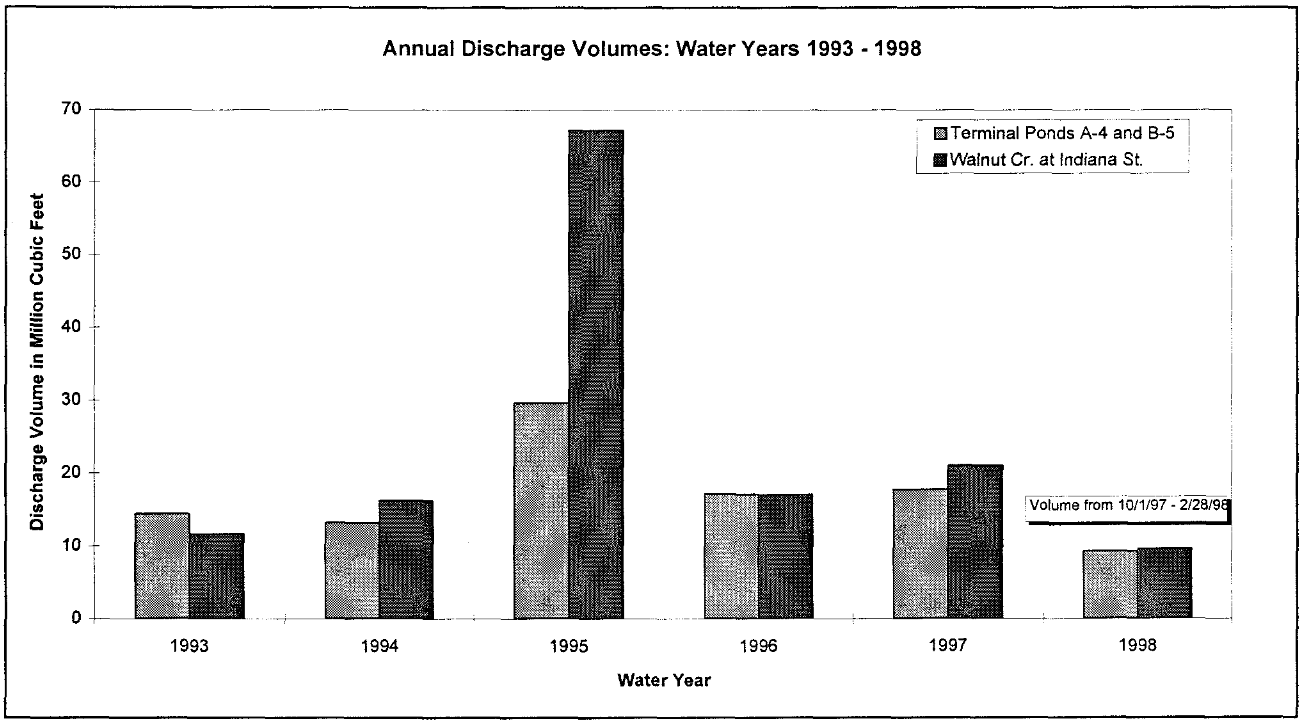

Figure 4-1. Annual Discharge Volumes for Walnut Creek.

[16] These Source Location stations were installed in response to the exceedances measured at GS03 as part of the source evaluation.

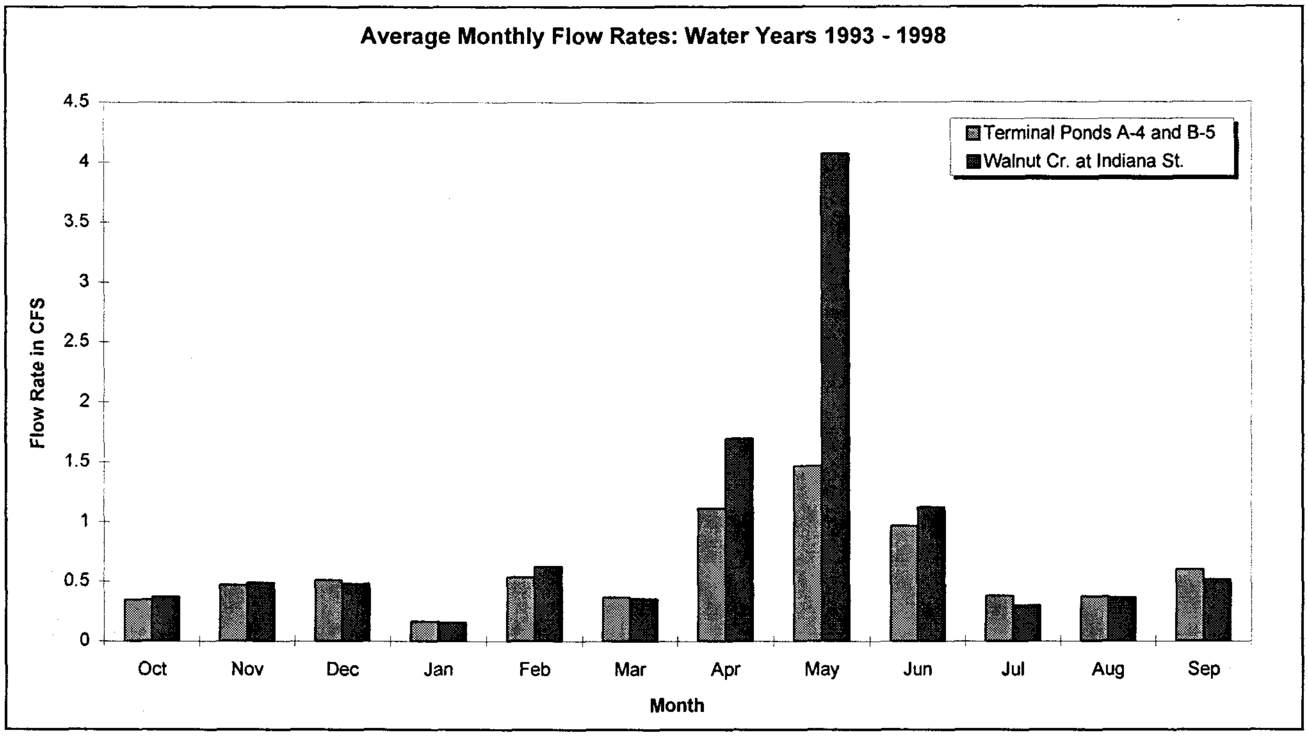

Figure 4-2. Average Monthly Flow Rates in Walnut Creek.

For reference, Figure 4-3 shows the relative surface-water discharge volumes from currently monitored subbasins contributing to GS03. The period of record is from October 1, 1997 through February 28, 1998.

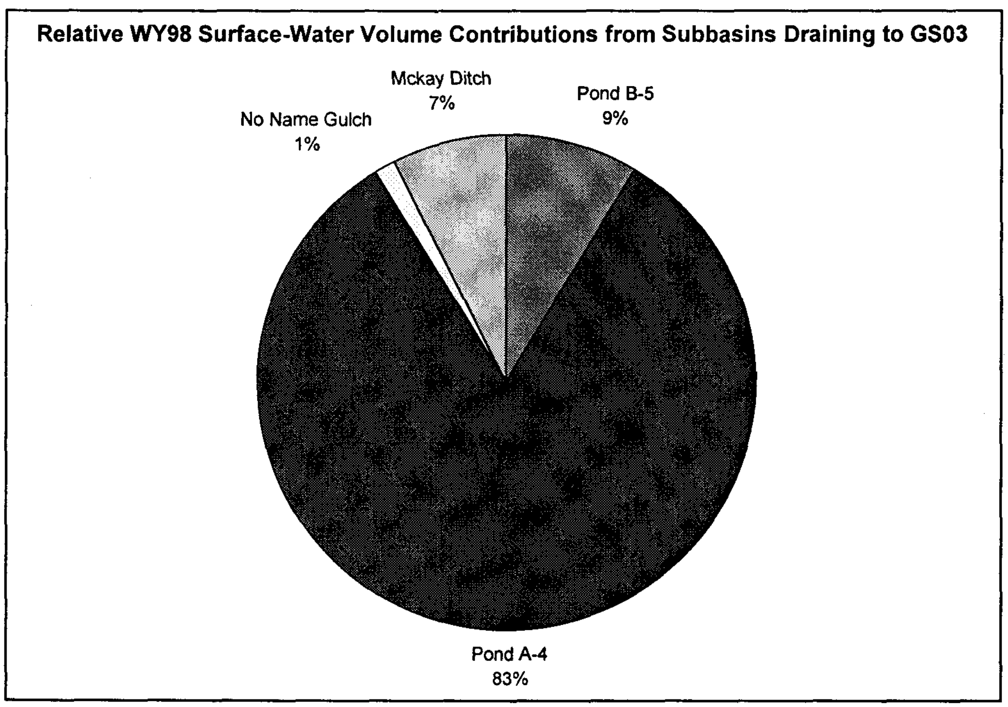

Figure 4-3. Relative WY98 Discharge Volumes for GS03 Subbasins.

Radionuclide Activities

Individual analytical results for Pu are shown in Figure 4-4. The higher values in WY95 for the terminal ponds were a result of very high runoff volumes and the subsequent "dam-safety"[17] discharge of Ponds A-4 and B-5 before adequate settling of contaminants could be achieved. All sample results are plotted regardless of sampling protocol employed[18]. The recent elevated results at GS03 occur on the right side of the plot. Inspection of the individual analytical results for GS03 displayed in Figure 4-4 suggests that one or more of the elevated sample measurements may be statistical *outliers* — a result consistent with either an exceedance or a possible data-quality problem.

Inspection of statistical means and standard deviations calculated for a log-normal (transform of the) data for GS03 indicate that the highest recorded Pu activity at GS03, 0.465 pCi/l, is more than 3 standard deviations from the mean. A log-normal distribution represents a much better approximation of the actual data distribution than a normal distribution. This results suggests the value may be an outlier. Importantly, though, there is no technical reason to question the validity of the datum.

Gilbert (1987) cautions against using statistical tests alone to determine or discard possible outliers since there is always a chance the test incorrectly declares the suspect datum an outlier. Given that the acceptance or rejection of a single sample datum - the GS03 sample value of 0.465 pCi(Pu)/L - has a critical influence on whether or not an exceedance of the 30-day average occurred, and because there is no technical reason to discount its validity, the Site has elected to continue to include this datum in assessment of the 30-day average.

Summary statistics for these results are shown in Table 4-1. These summary statistics indicate that there may be a decrease in water quality between the terminal ponds and Indiana Street during certain conditions. However, when the WY97 results are not included, the average activity at GS03 is not significantly different than the average activities for the terminal ponds. Therefore, the drainage may have changed somehow to give the elevated values, or the RFCA sampling protocols may be affecting the calculation of water-quality means and variance (see Section 5.3). Additionally, the increased number of grab samples and operational efficiency of the monitoring under RFCA may be accurately measuring water-quality variations that went unquantified during previous monitoring programs. In fact, the water-quality measurements collected under RFCA may be indicative of the actual variations occurring at GS03 from year to year. It should be noted that the activities in Table 4-1 are arithmetic averages, which do not take into account the hydrologic

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[17] See Procedure: Action Level Response Plan for Dams A-4, B-5 or C-2, RMRS/OPS-PRO.063, Date Effective: 03/20/98.

[18] Individual grabs, time-paced (scheduled grabs) composites, storm-event (hydrograph rising limb) flow-paced composites, and continuous flow-paced composites are shown. For a discussion of sample collection methods, see Section 6.2.4 in Progress Report #1.

conditions during sampling (storm-event, baseflow, etc.) or the flow rate (more importantly, the discharge volume) associated with the measured activity.

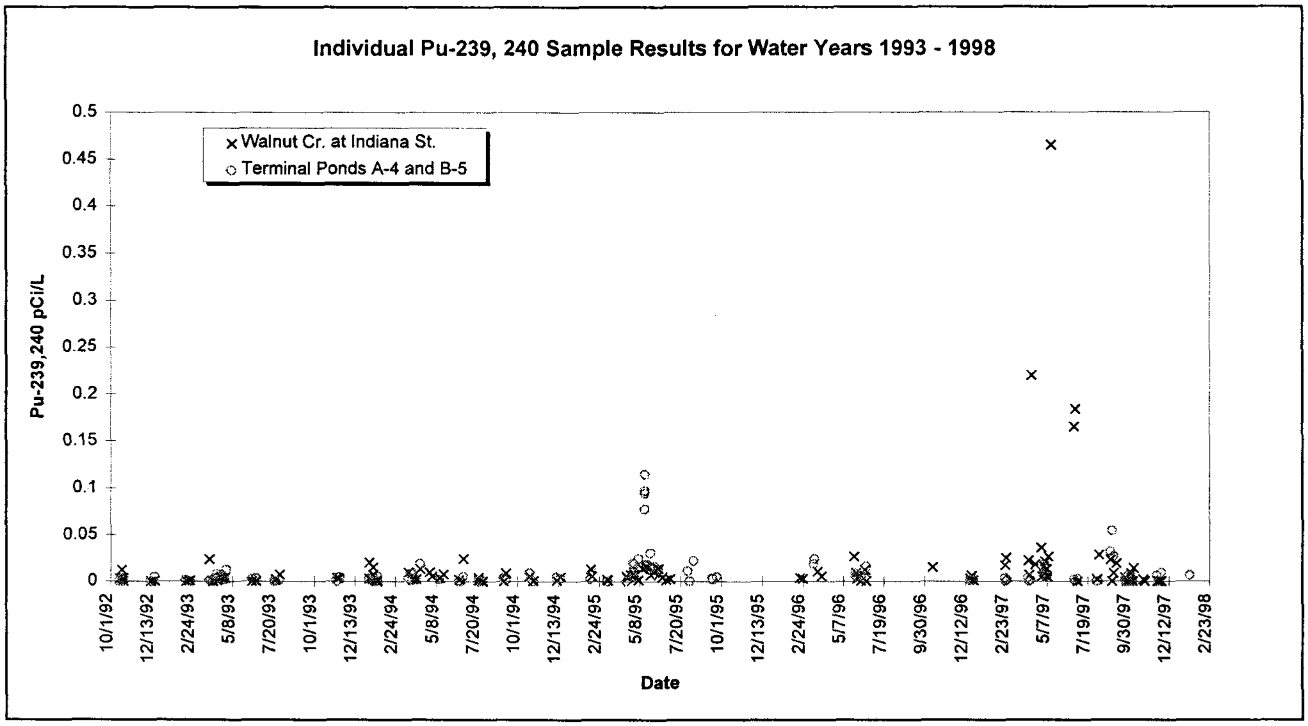


Figure 4-4. Individual Analytical Pu Results for Walnut Creek.

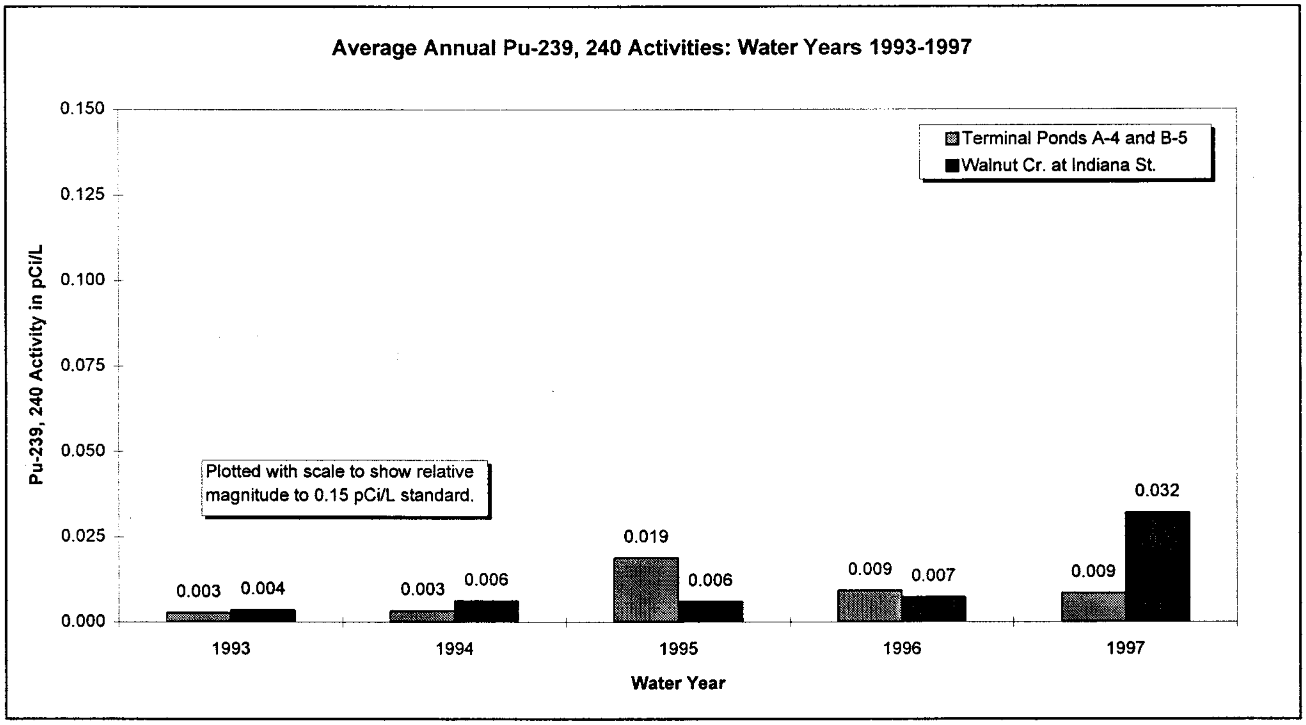
Figure 4-5 compares average annual activities in Walnut Creek for WY93 - WY97. For WY93 - WY96, simple arithmetic averages are plotted. However, due to the continuous flow-paced sampling protocols currently in place under RFCA, more representative, volume-weighted average activities are shown for WY97. It is important to note that although elevated measurements were made in WY97, the annualized GS03 volume weighted average for Pu is still below 0.05 pCi/l (0.032 pCi/l). Although average activities seem to have changed significantly, the changes are small when taken in context with the levels of activity (to less than 1/100th of a pCi) being measured. In fact, the apparent change in activity may be due to the change in sampling protocols, and not a reflection of actual changes in the drainage. This change in sampling protocols, from grab and storm-event sampling to continuous flow-paced sampling, was discussed in greater detail in Section 6.2.4 in Progress Report #1 and in Section 5.3 of this report.

Table 4-1. Summary Statistics for Plutonium Samples from Pond A-4, Pond B-5, and Walnut Creek at Indiana Street.

Sampling Location[a]	Number of Samples	Average[b] Activity (pCi/l)	Maximum Result (pCi/l)	Standard Deviation[c] (pCi/l)
Walnut Creek at Indiana Street				
GS03	42	0.034	0.465	0.083
W+I	68	0.006	0.026	0.006
All	110	0.016	0.465	0.053
Pond A-4				
GS11	29	0.006	0.054	0.012
A4EFF	72	0.007	0.097	0.016
All	101	0.007	0.097	0.015
Pond B-5				
GS08	7	0.005	0.017	0.006
B5Eff	18	0.023	0.115	0.028
All	25	0.018	0.115	0.025

[a] Rocky Flats Soil and Water Database System location codes are shown; GS03 and W+I are co-located; GS11 and A4EFF are co-located; GS08 and B5EFF are co-located.
[b] Arithmetic average
[c] Assumes normal distribution for simplicity.

It is generally agreed that Pu tends to form strong associations with particulate matter (see Section 9.1 in Progress Report #3 for a more detailed discussion and literature references). When contaminated particles are transported in surface water, and assuming that Pu mass correlates directly with the suspended particulate mass, then the observed Pu levels could be directly correlated with the amount of TSS. The data collected at GS10 is a good example (Figure 4-6) of this phenomenon. During high intensity precipitation events, with increased raindrop impact, higher quantities of solids are transported in overland flow. Similarly, higher flow rates in ditches and creeks generally result in increased TSS values due to higher flow velocity and turbulence which increase channel scour. Additionally, seasonal changes in biological and chemical processes may influence Pu transport. Figure 4-7 shows monthly arithmetic average activities which increase for months with higher rainfall and flow rates which are shown on Figure 4-2.



Volume-weighted WY97 average is plotted.

Figure 4-5. Average Annual Pu Activities for Walnut Creek.

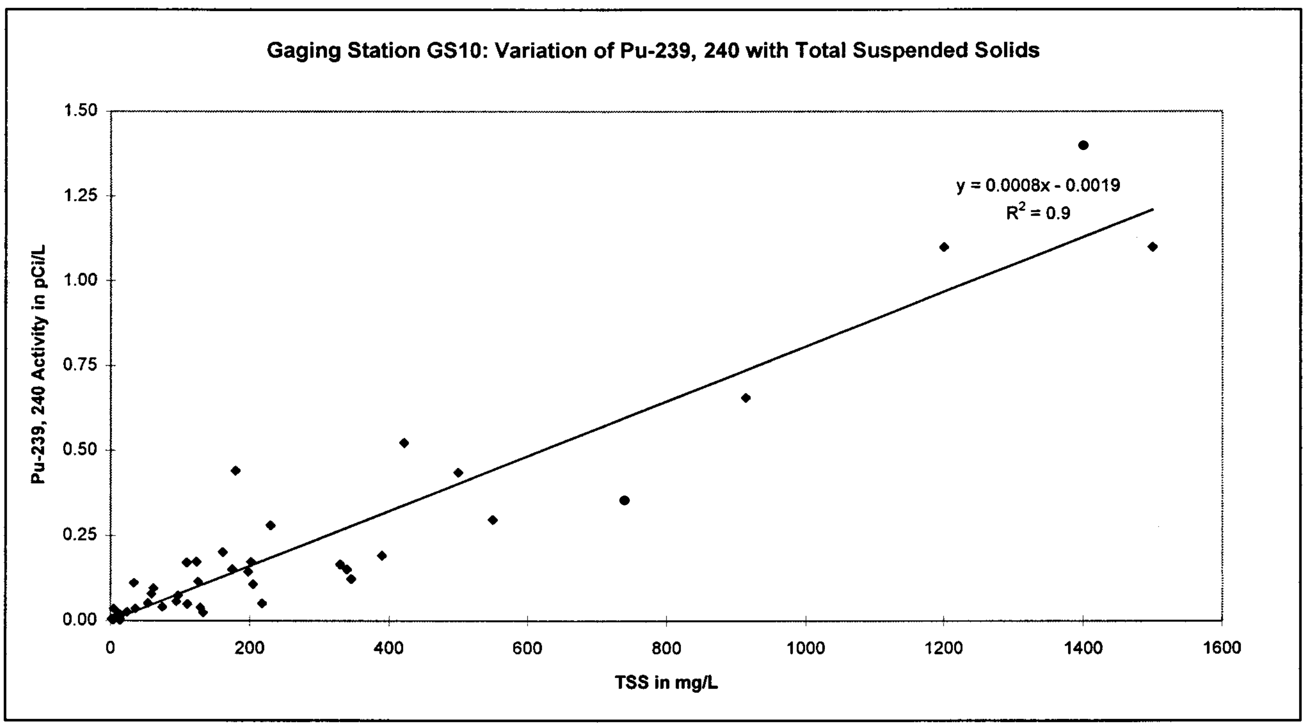


Figure 4-6. Variation of Pu with Total Suspended Solids at GS10.

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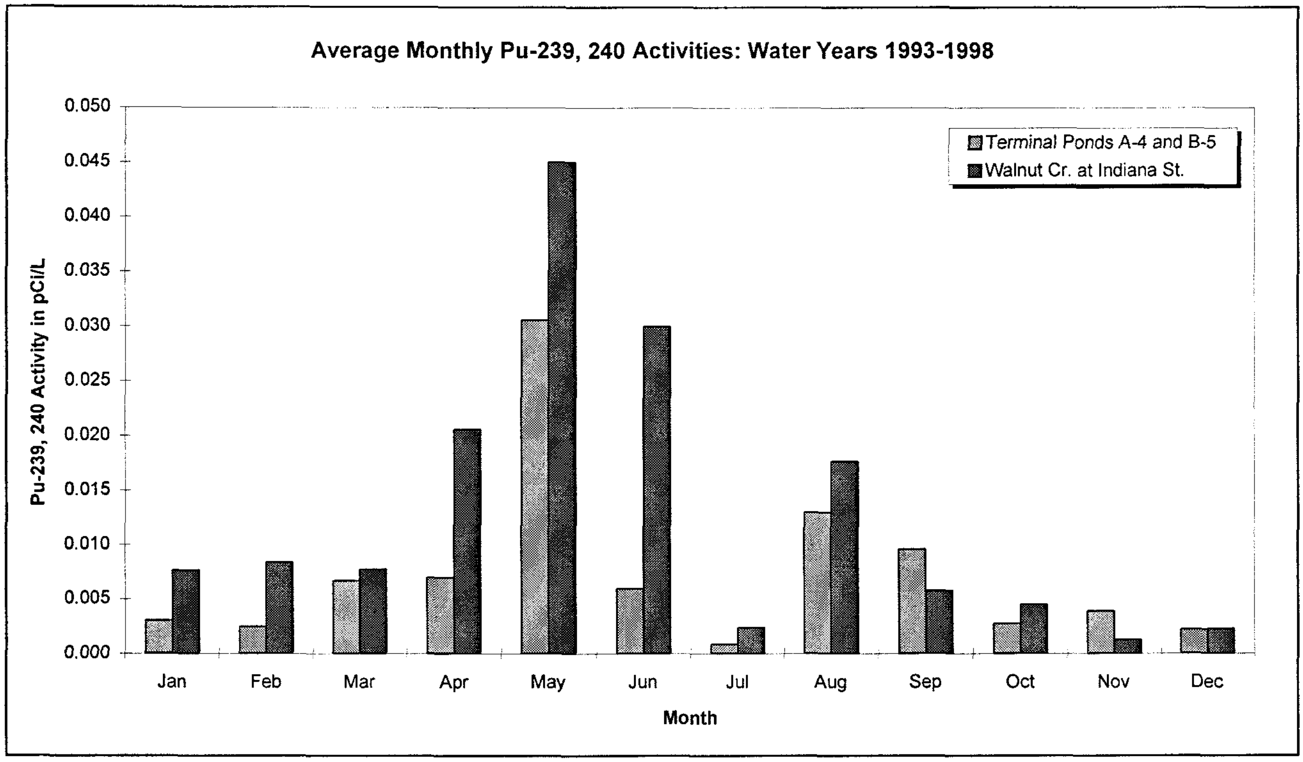

All averages are arithmetic.

Figure 4-7. Average Monthly Pu Activities in Walnut Creek.

Limited radionuclide data have been collected at new gaging stations GS33, GS34, and GS35 to date. Table 4-2 gives summary statistics for available samples.

Table 4-2. Summary Statistics for Plutonium Samples from GS33, GS34, and GS35.

Sampling Location[a]	Number of Samples	Average[b] Activity (pCi/l)	Maximum Result (pCi/l)	Standard Deviation[c] (pCi/l)
Walnut Creek above McKay Ditch				
GS34	None to Date	NA	NA	NA
No Name Gulch at Walnut Creek				
GS33	2	0.005	0.010	0.007
McKay Ditch at Walnut Creek				
GS35	2	0.001	0.001	0.001

[a] Rocky Flats Soil and Water Database System location codes are shown.
[b] Arithmetic average
[c] Assumes normal distribution

4.1.2. Loading Analysis

WY93 - WY98 Monitoring Data

Annual loads in micrograms are plotted in Figure 4-8. For WY93 - WY96, the annual arithmetic average activity of sample results is multiplied by the associated total annual discharge volume, then converted to micrograms. For WY97, the activity for each flow-paced composite sample is multiplied by the associated discharge volume during the sample, then converted to micrograms and totaled. When no result was available for a period with flow (usually due to NSQ or an equipment failure), the annual volume-weighted activity for the rest of the year was assumed for that period in order to estimate a load for comparison purposes. Figure 4-8 shows the relative magnitude of WY97 loads compared to previous water years.

The annual gain/loss in Pu load between the terminal ponds and Indiana Street is plotted in Figure 4-9. Losses in load are plotted as negative values. A gain indicates that Pu entered the stream reach between the terminal ponds and Indiana Street. A loss indicates that Pu was lost to the streambed or to the sediments in the GS03 flume pond. The result for WY97 stands out and suggests that a source may exist in the drainage area below the terminal ponds.

Seasonal loads in micrograms are plotted in Figure 4-10. For all water years, the seasonal arithmetic average activity is multiplied by the associated average seasonal discharge volume, then converted to micrograms. Figure 4-10 indicated that a majority of the load measured at GS03 occurs during seasons with higher flow rates and larger volumes of water (see Figure 4-2).

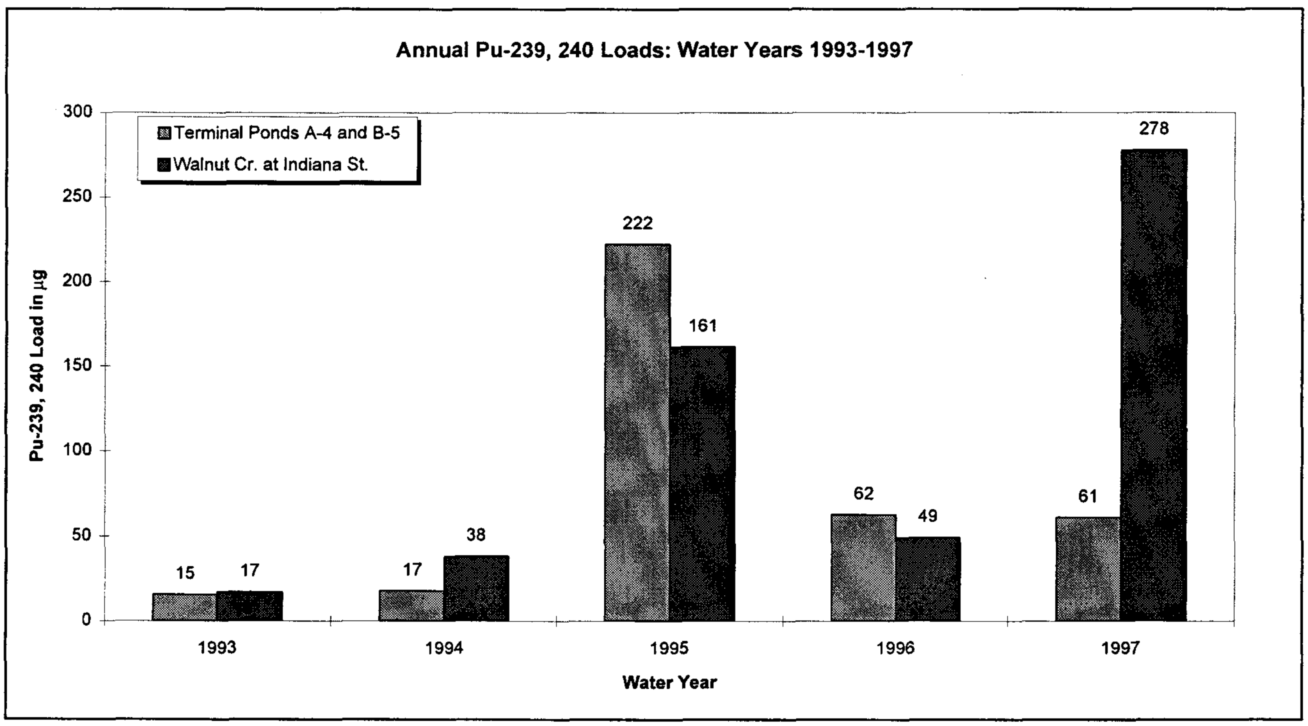

Figure 4-8. Annual Pu Loads in Walnut Creek.

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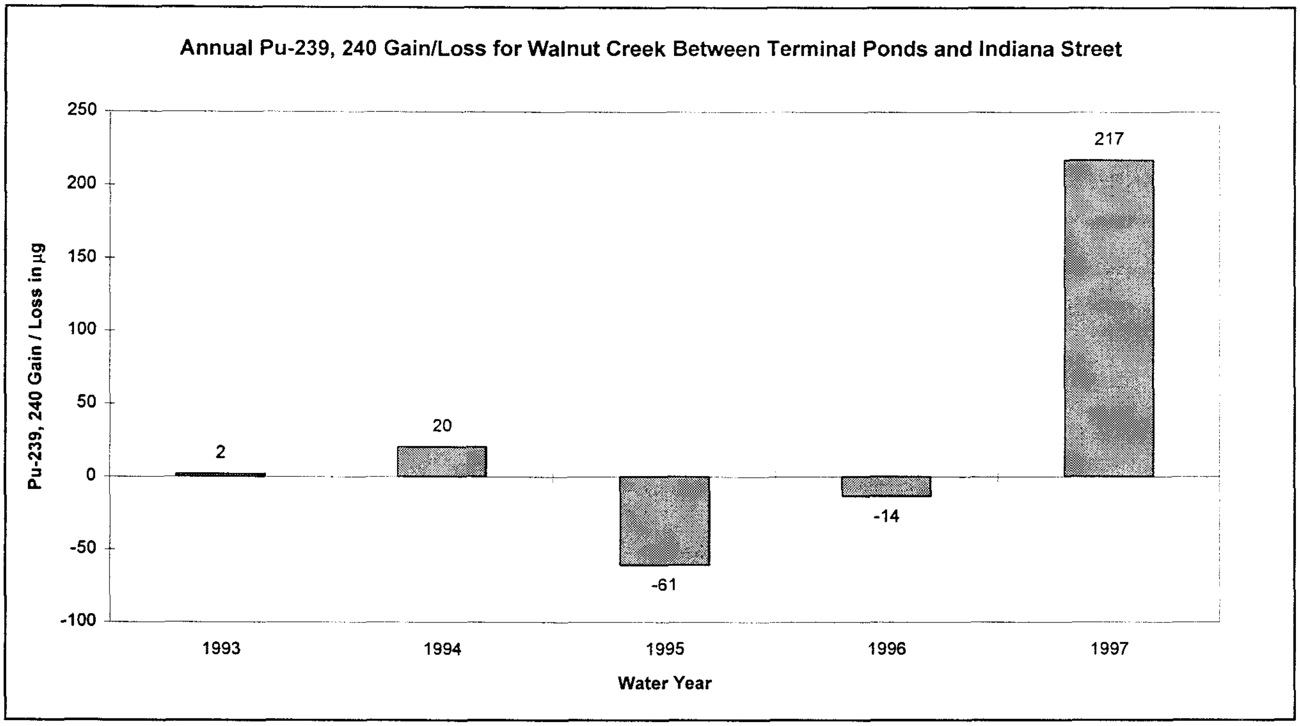
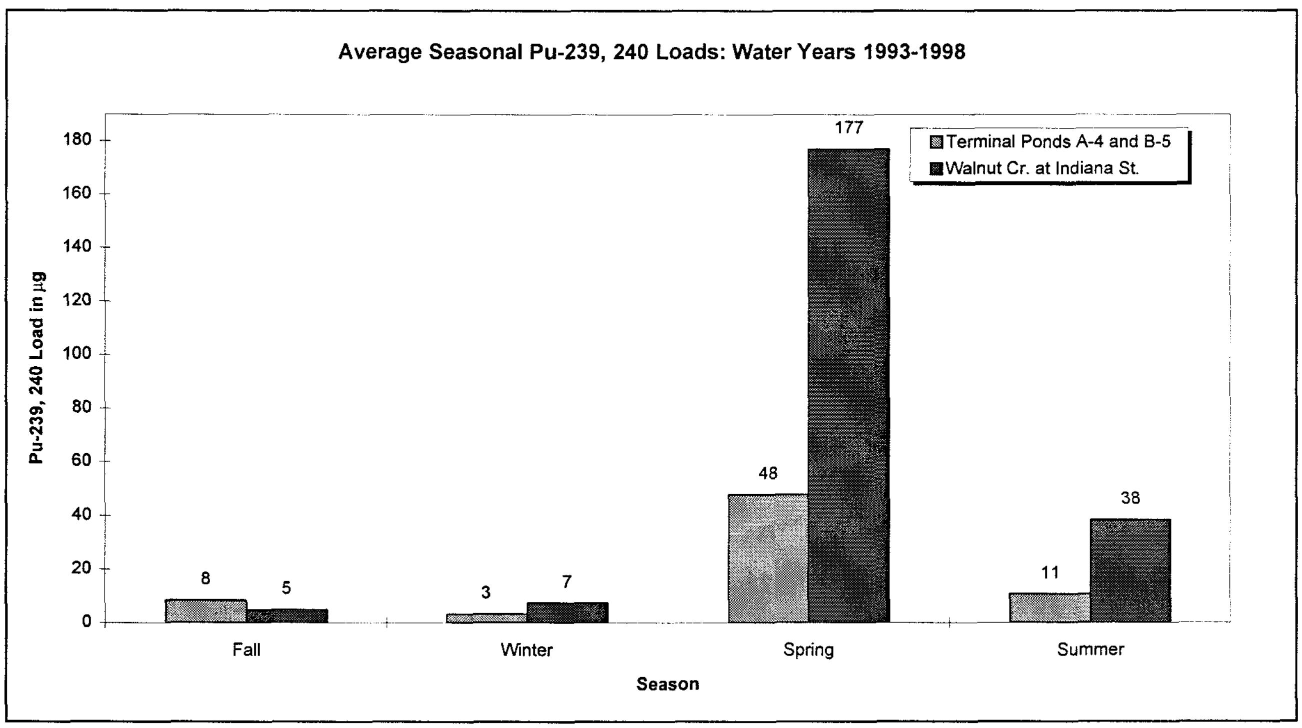


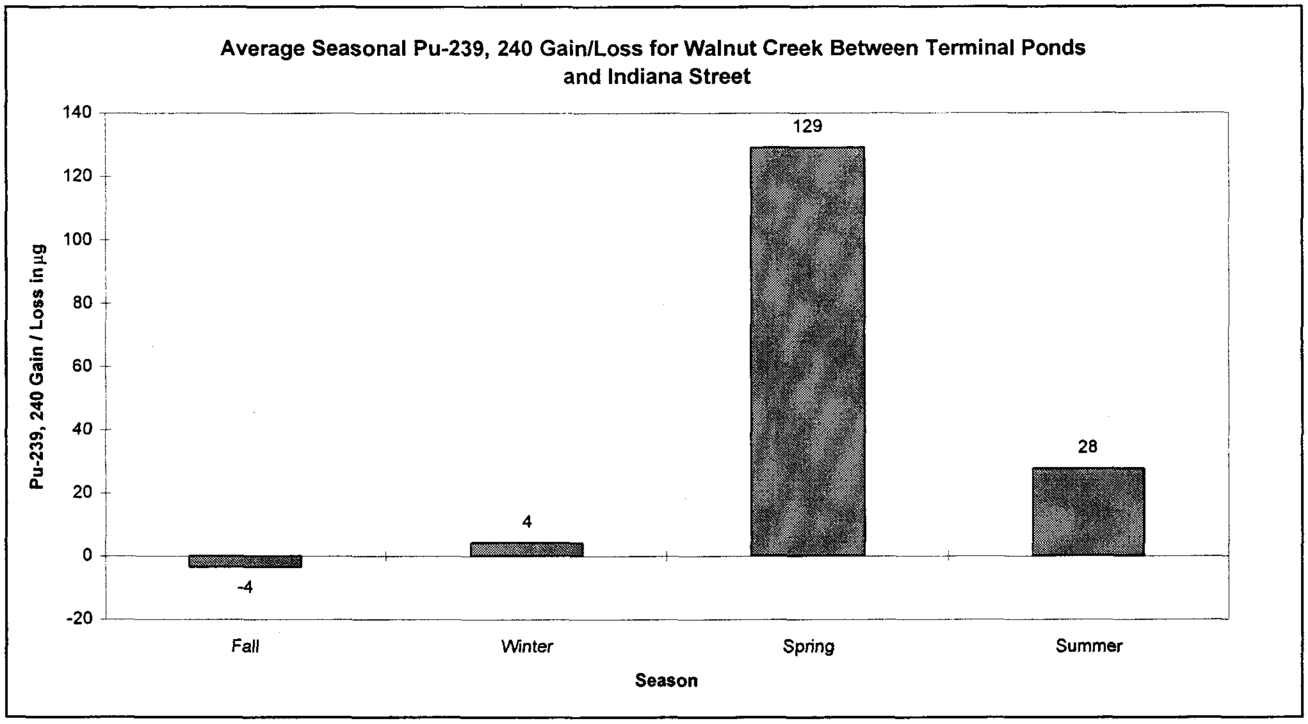
Figure 4-9. Annual Gain/loss of Pu for Walnut Creek.



Plot includes data through 12/4/97.

Figure 4-10. Seasonal Pu Loads in Walnut Creek.

The WY93 - WY98 average seasonal gains in Pu load between the terminal ponds and Indiana Street are plotted in Figure 4-11. A gain indicates that Pu entered the stream reach between the terminal ponds and Indiana Street. The largest gain occurs during seasons of higher precipitation and the associated overland flow and increased flow rates. The variation by season may also be indicative of environmental, physiochemical, or biochemical changes which could be influencing Pu transport.



Plot includes data through 12/4/97.

Figure 4-11. Seasonal Gain/loss of Pu for Walnut Creek.

WY97 and WY98 Continuous Flow-Paced Monitoring Data

This loading analysis includes gaging stations GS03 (Walnut Creek at Indiana St.), GS08, and GS11 (below terminal ponds B-5 and A-4, respectively). Source Location monitoring stations GS33, GS34, and GS35 are not included at this time due to the limited number of sample results available to date (see Table 4-2). These locations will be included and evaluated in future loading evaluations as part of the increased monitoring scope the Site has undertaken. Incorporation of loading data from the three new Source Location stations will help to quantify loads from the corresponding subbasins contributing to GS03. These evaluations will better define the loads from each subbasin to indicate the general location of any discrete sources or to support the hypothesis of a distributed diffuse source within the GS03 basin.

Figure 4-12 shows volume-weighted average monthly activities for continuous flow-paced samples collected in WY97 and WY98. Analytical results are available through December 4, 1997. For most months, the activity increases between the terminal ponds and Indiana Street.

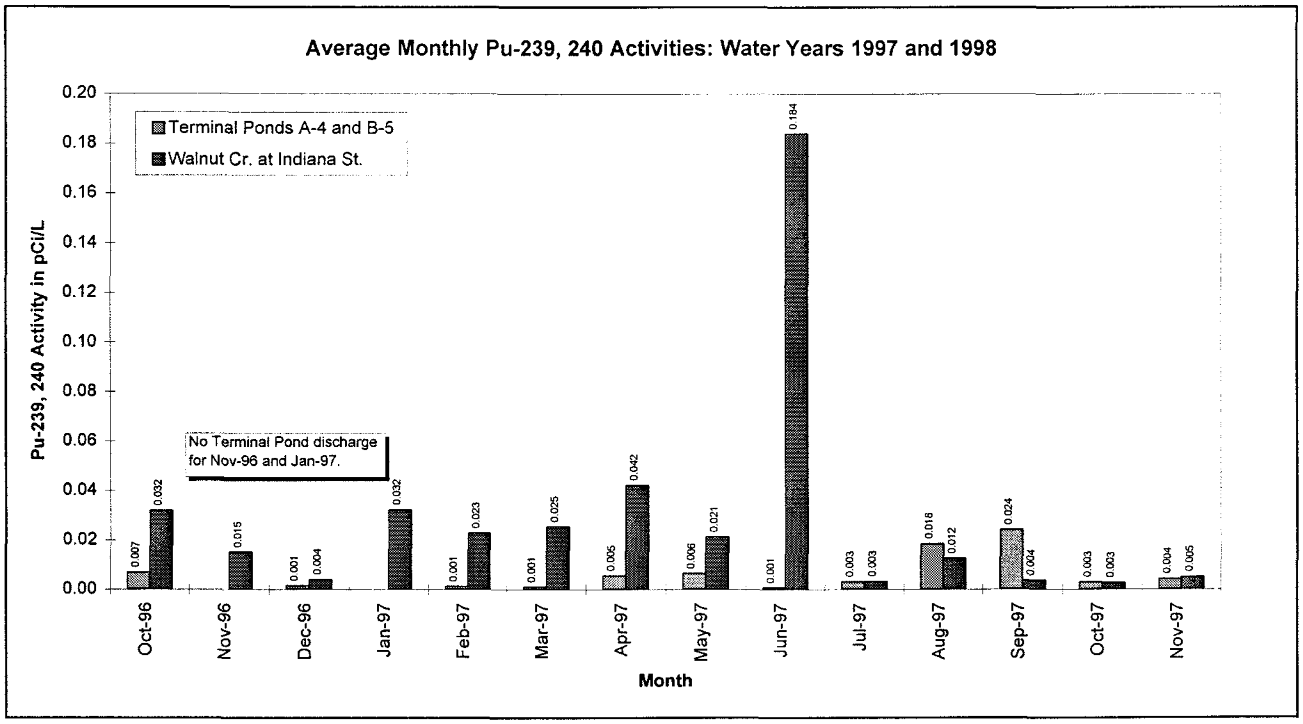


Figure 4-12. Average Monthly Pu Activities in Walnut Creek.

Detail for each continuous flow-paced composite sample at GS03 is presented in Table A-6. Elevated samples are indicated in bold. Detail for each continuous flow-paced composite sample at GS08 is presented in Table A-7, and detail for each continuous flow-paced composite sample at GS11 is presented in Table A-8. It is important to note the highly variable activity for the GS03 samples, especially for the three consecutive samples collected during a pond discharge during the period June 25, through July 6, 1997 which shows that the activity drops off dramatically for the last sample. This seems to indicate an intermittent source (assuming any contamination would not travel as plug flow), a localized source, or some sort of 'hot particle' mechanism (see Sec. 5.3). Regardless, it is apparent that the variability of surface-water activity and the transport mechanisms for Pu are not fully understood. Results of the ongoing AMS should provide insight into these variations (see Section 11.4).

Loads were calculated during terminal pond discharges to evaluate changes in loads as the discharge moved through the reach to Indiana Street. Figure 4-13 shows that for most discharges in WY97-WY98, loads increased between the terminal ponds and Indiana Street, indicative of a possible source in the drainage below the terminal ponds, or a tributary surface-water source.

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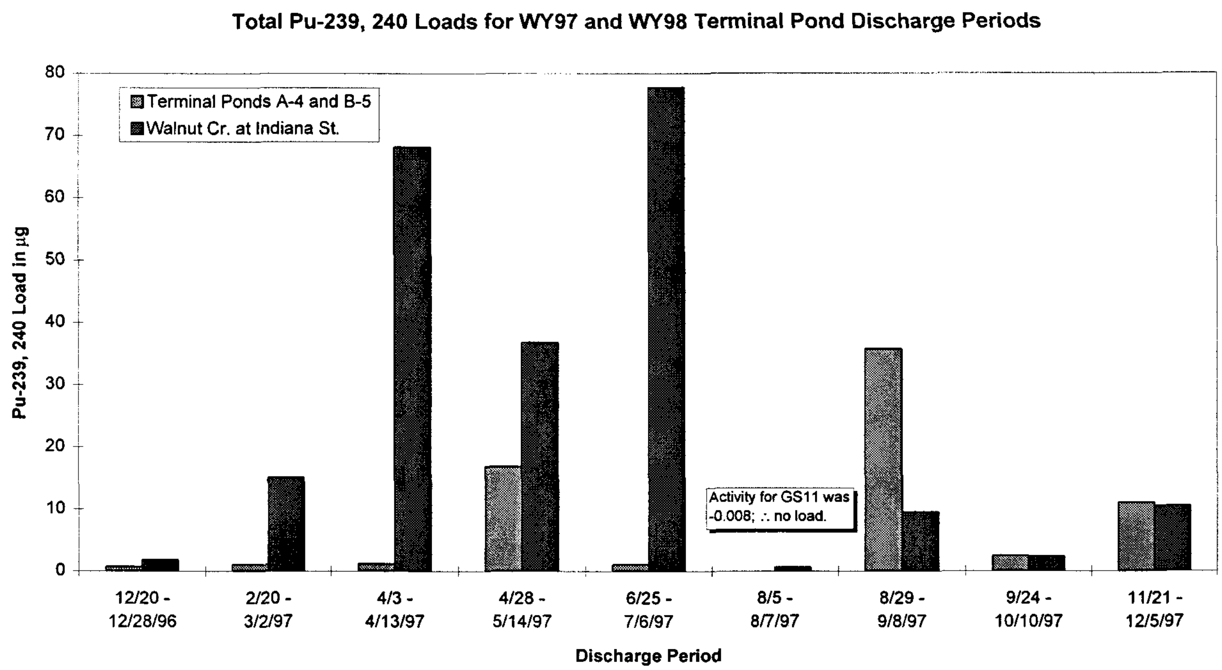

Figure 4-13. Walnut Creek Loads During WY97 and WY98 Terminal Pond Discharges.

4.1.3. Data Correlations

Flow Rates and TSS

As stated previously, Pu forms strong associations with particulate matter (as shown in Figure 4-6; references in Section 9 of Progress Report #3). When conditions favor transport of particulates in surface water, then Pu loading in water is similarly affected. During high intensity precipitation events, with increased raindrop impact, higher quantities of solids are transported in overland flow. Similarly, higher flow rates in ditches and creeks generally result in increased TSS values due to higher flow velocity, turbulence, and channel scouring. Unfortunately, few results are available for TSS at GS03. Recent sampling at GS03 has included TSS analysis, although results are often very low. Figure 4-14 shows the variation of Pu with TSS for recent samples collected at GS03. There are insufficient data to provide or test a correlation.

Figure 4-15 shows the variation of Pu activity with flow for GS03. The activity plotted is the analytical result for the composite sample; the flow is the average of the flow rates during each individual grab. Figure 4-15 shows no trends that are indicative of a Pu source influenced solely by flow rate. An upward trend would indicate the increased movement of Pu during higher flow rates. This can occur when the source is widespread (increased movement through overland flow), or when the source exists in the streambed itself (increased movement through scouring). These are the mechanisms commonly seen at other Site monitoring locations, however, Figure 4-15 seems to indicate that these mechanisms are not controlling. Conversely, it may also indicate that there are multiple, potentially intermittent, mechanisms

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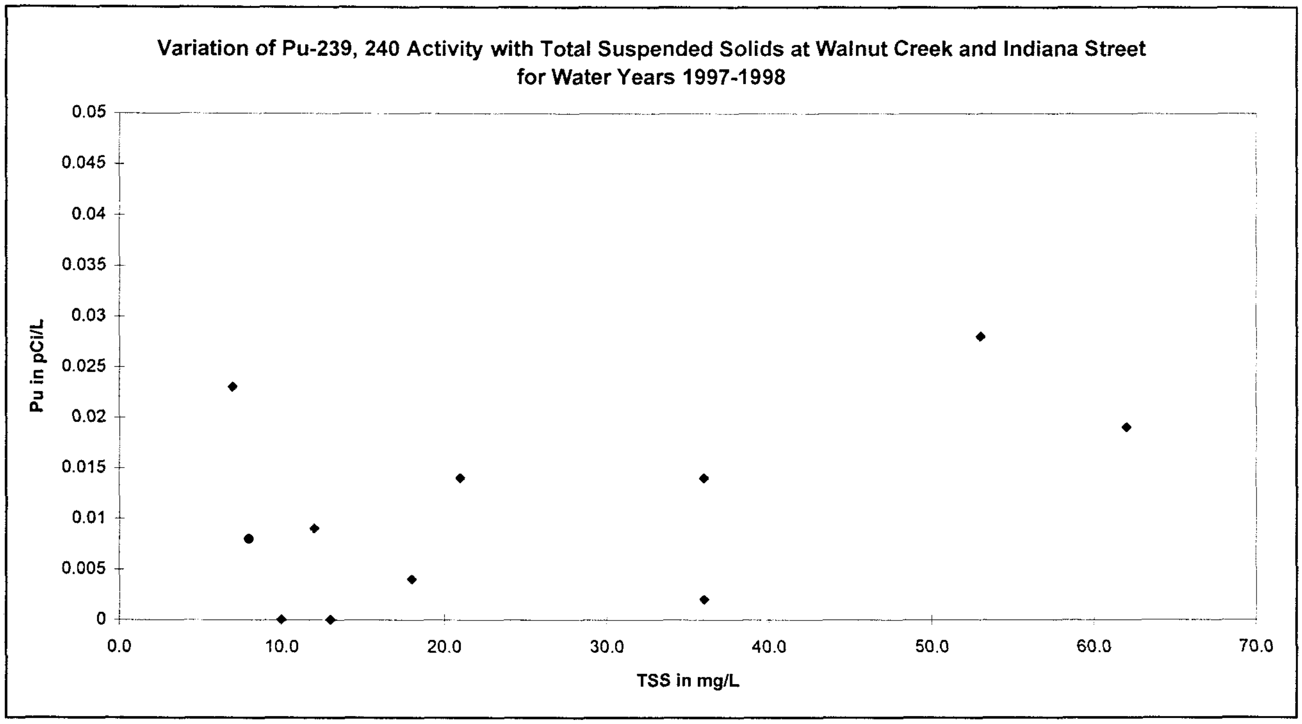
and sources. The AMS will include an evaluation of TSS in surface water and the associated radionuclides. This analysis should provide some insight into the transport mechanisms of Pu which is or is not associated with particulate matter.



Results below the detection limit of 5 mg/l TSS are not plotted.

Figure 4-14. Variation of Pu with TSS at GS03.

Variation could be caused by variations in precipitation, some physiochemical or biological phenomena, some 'hot particle' mechanism, radiochemical analyses by different subcontractor laboratories, or a changing drainage basin. For example, similar precipitation events with similar runoff rates could give different activities if the precipitation was more intense on a localized source area. Precipitation runoff transporting soils from relatively contaminated areas could result in higher Pu to flow ratios, and vice versa. Regardless, it is apparent that transport of actinides in the environment and the associated variability is not fully understood.

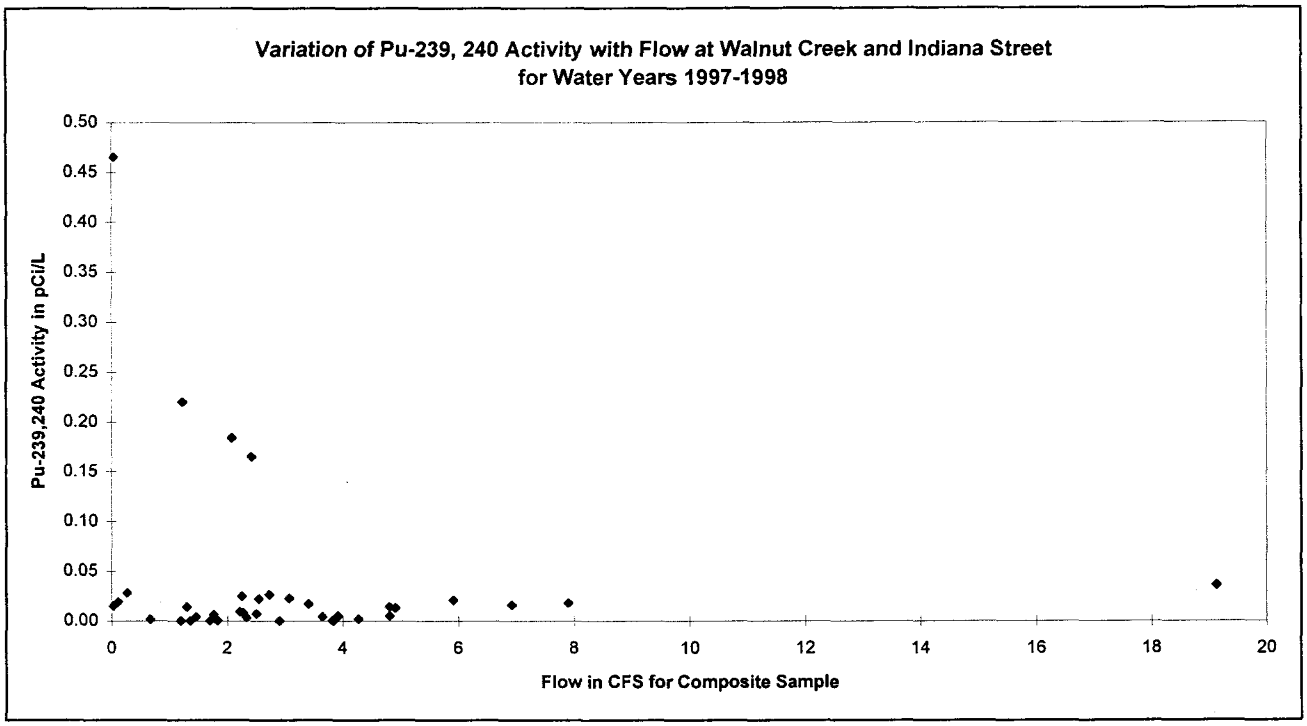


Figure 4-15. Variation of Pu Activity with Flow Rate at GS03.

4.2. 1998 SOIL SAMPLING IN THE WALNUT CREEK WATERSHED

In February 1998, soil sampling was conducted at 51 locations in the Walnut Creek Watershed shown on Figure 4-16. Each surface soil sample location was sampled by the Rocky Flats Plant Soil Sampling Method (RMRS Procedure 4-E42-OPS-GT.08). The sampling method employs a grid and template system to obtain a bulk sample of the upper five centimeters of soil. Each sample was analyzed for Pu and Am by alpha spectrometry per Site analytical and quality assurance requirements. The preliminary analytical data are shown in Table A-9 of Appendix A. These data have been preliminarily reviewed by the Site. Analytical results that did not pass quality control requirements are not provided herein and are being rerun. The data have not yet been validated.

The soil sampling requirements for the source investigation are described in the *Sampling and Analysis Plan for Investigation of Surface Soil Actinide Content in the Walnut Creek and Woman Creek Watersheds at the Rocky Flats Environmental Technology Site* (RMRS, February 2, 1998). A backup aliquot was collected and held for each location in the event that additional analyses are required. Three field duplicate samples were collected for evaluation of sampling and analysis reproducibility. All applicable procedures for the soil sampling were followed.

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Site personnel established the soil sampling locations using five-foot contour mapping. Site personnel also made field observations of the hydrologic and pedologic conditions of the soils at each sampling location. Field observations included: vegetative cover, canopy height, Munsel color code for soil color, soil type and texture, and any rilling observed. The geographic coordinates of the soil sampling locations (as marked by stakes) were determined by Global Positioning System (GPS) by Site personnel within one week from completion of the soil sampling.

4.3. SOIL SAMPLE LOCATION SELECTION

The sampling locations in the Walnut Creek drainage were selected by statistical methods described by Gilbert (1987). Gilbert describes a simple statistical method for locating sources of contaminants using grid systems. A triangular grid system is preferred and has been shown to likely provide more information than a square grid (Parkhurst, 1984). Definition of data quality objectives included a circular target (circular contamination source) with a minimum diameter of 400 feet, and a 10% acceptable probability of not finding the source. Following methods detailed in Gilbert (1987), these parameters determined a grid spacing of 800 feet for sample collection.

In summary, the surface soil sampling in the Walnut Creek watershed was designed to locate a 400 foot diameter circular target source with 90% confidence of finding the source if one exists. Again, for reference, this source size would fit inside the area of the 903 Pad.

4.4. PARTICLE SIZE DISTRIBUTION OF ACTINIDES

An important objective of the soil sampling and analysis project is to obtain data on the particle size distribution of the radionuclides in the soil. Therefore, soil samples collected at nine locations and sediment samples collected at three locations in the Walnut Creek Watershed (Figure 4-16) are being fractionated by sieve and gravity settling analysis to determine the relative percentages of sand-silt and clay-sized (<.2 mm, <.01 mm, and <.002 mm respectively) particles in the samples. The sediment samples are from stations 16797, 16297, and 15697 from the Phase I investigation (Figure 3-18 in Progress Report #2). The particle size separations are being done by Dr. James Ranville under the supervision of Dr. Bruce Honeyman at the Colorado School of Mines. Each of the particle size fractions will be analyzed for Pu and Am to provide a particle size distribution of actinides in the soils and sediments.

The locations, shown in blue on Figure 4-16, were sampled for analysis of total Pu and Am in a homogenized, bulk soil samples. The locations shown in magenta on Figure 4-16 were sampled for bulk analysis of Pu and Am, and for Pu and Am in the sand, silt, and clay size fractions. Therefore, four analytical results will be obtained for each of the locations shown in magenta. These results will be presented in future reports.

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4.5. WATER EROSION PREDICTION PROJECT MODELING

Figure 4-16 shows how the watersheds have been preliminarily divided into logical drainage sub-basins (in red) with hillslope configurations suitable for erosion modeling using the Watershed Erosion Prediction Procedure (WEPP) model. The soil particle size distribution an associated actinide content data will be used to calibrate the WEPP model for the AMS. This model will be used to simulate and predict soil erosion in the Site watersheds as discussed further in Section 11.4.

4.6. PRELIMINARY CONCLUSIONS

The soil actinide activity data were received just a few days prior to publication of this Progress Report. The data have not yet been properly reviewed, mapped, or analyzed to produce final conclusions about the presence or absence of a definitive source of Pu or Am in the Walnut Creek watershed soils. However, the preliminary data indicate that total Pu-239,240 activity in the soils ranged from 0 to 2 pCi/g and Am-241 activity in the soils ranged from 0 to 0.7 pCi/g. Summary statistics are given in Table 4-3, and a frequency plot for the results is shown in Figure 4-17. Individual sample results are given in Table A-9.

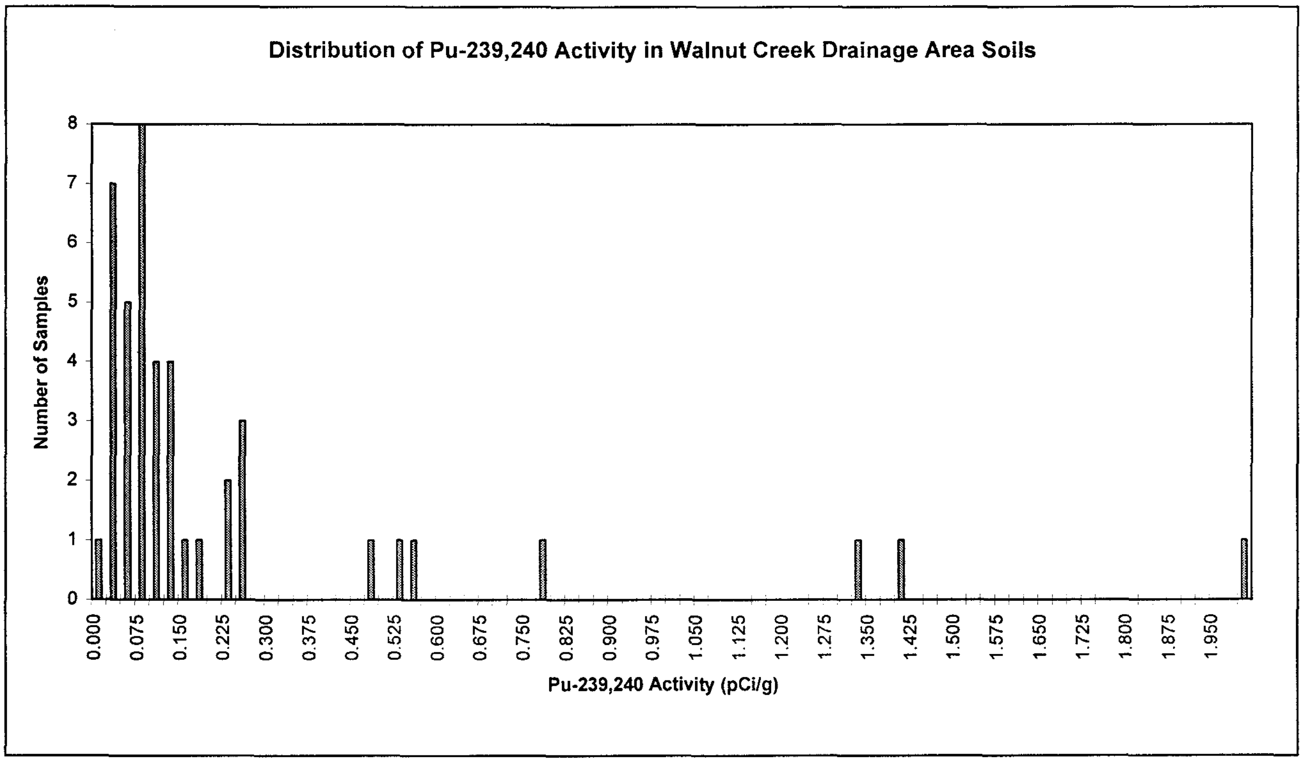

Figure 4-17. Distribution of Pu-239,240 Activity in Walnut Creek Drainage Area Soils.

Table 4-3. Summary Statistics for Soil Samples in the Walnut Creek Drainage Area: February 1998.

	Am-241	Am-241 Error	Pu-239,240	Pu-239,240 Error
Average	0.074	±0.043	0.231	±0.105
Minimum	-0.014	±0.024	-0.011	±0.015
Maximum	0.675	±0.096	1.990	±0.423

Notes: 1) Data are preliminary and subject to revision.

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5. GS03 SOURCE EVALUATION

In the previous Progress Reports, a discussion of possible source hypotheses was included. The following section in this Final Report includes those hypotheses which are still considered possible causes of the elevated measurements at GS03. In the following section, a discussion of source hypotheses is presented. To date, a singular source for GS03 has not be identified. Information collected to date does not point to any singular conclusion. In fact, it is entirely possible that multiple sources and transport mechanisms are responsible for the elevated activities at GS03. *To date, no localized areas of radiological contamination have been identified — either historical or resulting from current operations. The Site concludes that the likely source of the exceedance of the 30-day average for Pu and Am at POC GS03, resulted from diffuse radionuclide contamination from past Site operations released to the environment through events and conditions over past years.*

5.1. WIDESPREAD OR LOCALIZED SOIL AND SEDIMENT CONTAMINATION IN GS03 DRAINAGE

<u>**Soil Contamination**</u>

Site soils have received contamination from various historical releases. Section 3.7 in Progress Report #1 identified events from the Site's production era which introduced radionuclides to Site drainages via both airborne and surface-water runoff pathways. Historical reports, the Final Phase I RFI/RI Walnut Creek Priority Drainage Operable Unit 6 (OU6) Report, and a review of existing soil/sediment data indicate relatively low-level, dispersed Pu contamination of soils and sediments in the Walnut Creek drainage. Specifically, the OU6 report acknowledged that past production mission activities from 1952 through 1973 resulted in the release of significant amounts of Pu-contaminated surface waters to North and South Walnut Creeks, both tributary to GS03. The B-Series pond reconstruction efforts from 1971 through 1973 were estimated to have re-mobilized several curies of Pu-contaminated sediments, most of which would have been re-deposited in Pond B-1. Unknown amounts would have continued downstream and been deposited along South Walnut Creek, and subsequently Walnut Creek. Further, airborne contamination has resulted in widely distributed contamination, with levels diminishing with distance from sources such as the 903 Pad (Liator et al., 1995). The investigation, however, has revealed no new or previously unidentified Pu source areas (i.e., those well in excess of background) within the areas tributary to GS03.

Diffuse contamination from past Site operations in the form of stream sediments could affect water quality intermittently, as indicated by the occasionally elevated activities observed at GS03 (discussed in Section 3, Progress Report #1). The movement of contaminated stream sediments may have resulted in localized contaminated deposits or more evenly distributed contamination, depending on how active natural erosion processes are in Walnut Creek. As the drainage evolves over time, contaminated sediments initially buried, might be re-exposed, especially during periods of high flows by erosion of the stream bed and banks. These deposits might then be re-mobilized and transported through the drainage. Eventually, with repeated mobilization, contaminated sediments might be 'flushed' from the system as the localized deposits are exhausted.

As part of this source evaluation and in conjunction with the AMS, soil and sediment sampling was performed in the GS03 drainage to assess the extent of contamination in the GS03 drainage. Sediment sample results from August 21, 1997 show activities in the range of 0 to 1 pCi/g Pu (see Section 3.3 and Figure 3-20 in Progress Report #2). The arithmetic average activity for these samples was 0.27 pCi/g, with a maximum of 2.32 pCi/g. Preliminary results from the 51 soil samples taken in February 1998 from the Walnut Creek watershed (discussed in Section 4.2) indicate an average activity of 0.23 pCi/g, with a maximum of 1.99 pCi/g. Again, the investigation has revealed no new or previously unidentified Pu source areas (i.e., those well in excess of background) within the areas tributary to GS03.

<u>Suspended Solids in Surface Water</u>

Average soil activities across the drainage and observed TSS concentrations in surface water are barely sufficient to yield the observed surface-water Pu activities at GS03, when considering a simplistic model of overland flow Pu association with soils. As stated previously, Pu tends to form associations with particulate matter. The mass of this particulate matter is measured in surface water as TSS. Soil and sediment activities for samples in the GS03 drainage are generally below 2 pCi/g (generally ranging from 0.1 to <5 pCi/g). Activities in nearby, non-tributary areas have been measured at up to 7 pCi/g. Assuming that Pu is associated with soil solids measurable as TSS, and that TSS represents a uniform suspension of all soil fractions (i.e. TSS maintains the same particle size and composition ratios as the surface soils), surface water activity could be calculated directly from soil activity for a given TSS concentration. Table 5-1 presents the results of such calculations. Specifically, Table 5-1 shows the calculated surface water sample activities at GS03 which would result from a given basin soil activity, assuming uniform suspension of surface soils as TSS and complete association of Pu with TSS in solution. The ranges of TSS concentrations and basin soil activities used in the calculations are based on actual, observed values from the GS03 basin.

Table 5-1. Calculated Surface Water Activities Assuming Uniform Soil Suspension and Complete Association of Pu with Suspended Solids for GS03.

	Total Suspended Solids (TSS)	
Basin Soil Activity Ranges (pCi/g)	**18 mg/l (Average)**	**62 mg/l (Maximum)**
0.20 to 0.50	0.004 to 0.009 pCi/l Pu	0.012 to 0.031 pCi/l Pu
2.0 to 7.0	0.036 to 0.126 pCi/l Pu	0.124 to 0.434 pCi/l Pu

Based on calculations summarized in Table 5-1, the elevated activities observed at GS03 are possible; however, the conceptual model of uniform suspension of surface soils as TSS is an over-simplification. Although widespread low-level contamination is acknowledged for soils within the Walnut Creek drainage basin, the pond discharge conditions under which elevated Pu values were observed in 1997 at GS03 (for which no precipitation occurred) are not consistent with the theory of overland flow as the source of contamination. As noted in Section 3.2.3 of Progress Report #1, samples collected during Pond A-4 discharges with concurrent precipitation (which promotes overland flow) showed normal activities (0.022, 0.007 pCi/l). If runoff response from overland flow could be measured at GS03, any associated contaminated sediments would be available for sampling. Similarly, samples during high runoff periods in the period of April 24 through 29, 1997 (up to approximately 45 cubic feet per second (cfs) at GS03), showed low levels of Pu.

Fractionation

Fractionation of both soils in surface water runoff and radionuclides in soils is undoubtedly occurring in the drainage. As stated previously, the conceptual model of uniform suspension of surface soils as TSS is an over-simplification. Both mechanical and physiochemical suspension mechanisms suggest preferential suspension of certain fractions of the surface soil in stormwater runoff. Fractionation may occur as a function of particle size, density, and/or surface chemistry. Furthermore, Pu may associate preferentially with certain fractions of the soil based on surface area and/or surface chemistry. The net results may be a drastically different specific activity of suspended material in the surface water as compared to specific activity of the surface soils.

Sample results from RFCA Performance Monitoring Location, GS27 (Figure 2-1), provide a good example of this fractionation phenomenon. GS27 is an excellent test case because it has a very small drainage basin, approximately one acre of pavement and exposed soils, and stormwater runoff activities are significantly higher than the detection limits for Pu. Soil activities in the area range from 0.1 to 10 pCi/g. Measured TSS concentrations at this location range from 12 to 1,650 mg/l. For a Pu activity of 10 pCi/g in the soil and a sample with 1,650 mg/L TSS, the surface-water suspended activity would be 16.5 pCi/l, assuming uniform suspension. With actual observed Pu activities of 30 to 75 pCi/l and a maximum of 90 pCi/L, the data may suggest that Pu is preferentially suspended in surface water, perhaps associated with a preferentially suspended fraction of the surface soils. Figure 5-1 shows a comparison of sample activity with TSS, where sample activity is normalized to solids concentration in the sample.

No clear correlations are apparent in Figure 5-1; however, the elevated values of specific activity at low sample TSS concentrations dispute a simplified conceptual model of uniform association and suspension. If Pu associated uniformly with suspended material in a simple mass to mass ratio, the relationship would fit a horizontal line. In other words, in the event of no preferential sorption, the activity of the samples normalized to mass of solids would show no correlation with solids concentration (TSS). Instead, there is significant variation from a mean activity to mass ratio, particularly for the low TSS samples. Similar patterns to that shown in Figure 5-1 for GS27 data are observed for GS03, GS10, and SW093 data.

Similar indications of preferential suspension of Pu and/or Pu-associated solids are apparent when considering data from across the Walnut Creek drainage. Approximate basin soil activities are compared to maximum observed TSS activities for various Walnut Creek sub-basins in Table 5-2.

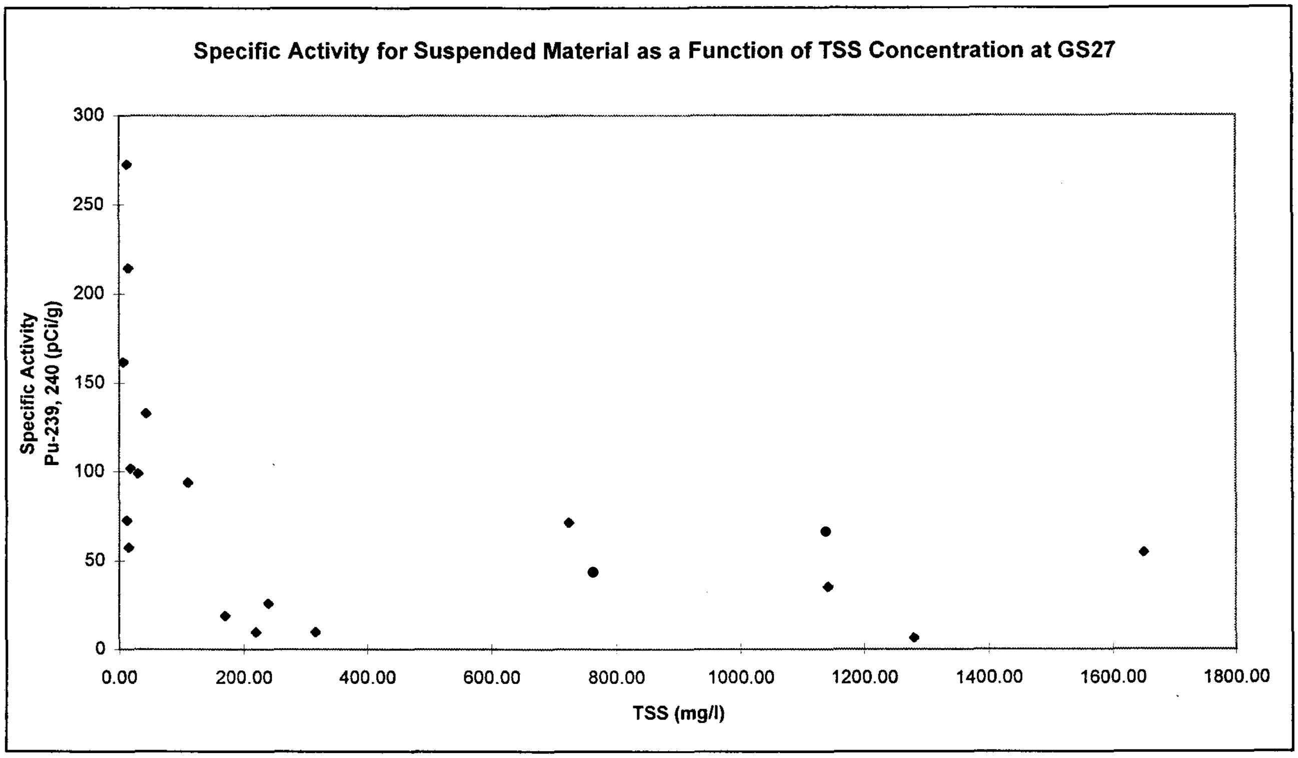

Figure 5-1. Specific Activity of Suspended Material as a Function of TSS Concentration in Stormwater Samples from GS27.

Table 5-2. Calculated Activities of Suspended Material in Surface Water Samples for Gaging Stations GS03, GS10, SW093, SW022, and GS27.

Monitoring Location	Approximate Basin Soil Activity (pCi/g)	Maximum TSS Activity* (pCi/g)
GS03	< 1.0	3.29
GS10	1.0	7.0
SW093	1.0	11.83
SW022	1.0	27.27
GS27	5.0	272.3

*TSS activities in Table 5-2 were calculated from total sample activities and suspended solids concentrations. It should be noted that in performing these calculations, it is assumed that all Pu in the surface water samples is associated with suspended material measured as TSS.

In all cases, the maximum calculated TSS activity is dramatically higher than the approximate basin soil activity, which may indicate both selective association of Pu with a certain fraction of the soil and preferential suspension of that fraction by surface water runoff.

Many hypotheses about the mechanisms of suspension, association, and subsequent transport of Pu in surface water can be formulated from these data. Relevant variables may include particle size and surface area as well as the nature of mineral and organic coatings. Consultation with the AMS scientists is in

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progress in an effort to resolve some of these uncertainties and identify any relationships which may lead to a greater understanding and the ability to predict and control radionuclide transport. Specifically, the AMS is evaluating soil/sediment and surface-water TSS speciation and the associated radionuclide activities to provide additional insight into transport of Pu in surface water.

5.2. TRIBUTARY SURFACE-WATER SOURCE

Another hypothesis to address is that radionuclide contamination of surface water observed at GS03 originated from surface-water tributaries to the Walnut Creek drainage. Two noteworthy tributaries, McKay Ditch and No Name Gulch, converge with Walnut Creek between the terminal ponds and GS03.

Several facts suggest that contaminated water sampled at GS03 did not originate as contaminated water in McKay Ditch and No Name Gulch. First, the high Pu activity recorded from the composite sample started on May 15, 1997 was collected during conditions of low flows. The flow rates observed at GS03 during collection of this sample (on the order of hundredths of a cfs) were likely much greater than any flow rates in the contributing tributaries. Further, No Name Gulch has a detention pond (possibly an old agricultural reservoir), which detains some runoff in No Name Gulch, dramatically increasing the amount of precipitation required to produce flows reaching Walnut Creek. Second, two composite samples collected at GS03 showed elevated levels of Pu, despite the fact that there was no significant precipitation during the sampling period to produce runoff in the major tributaries. Finally, composite samples taken at GS03, encompassing the significant runoff event of April 25 through 29, 1997 yielded no elevated radionuclide activities. Peak flow rates reached approximately 45 cubic feet per second at GS03 during the period April 24 through 29, 1997, indicating that tributaries likely contributed high flows correspondingly. If surface water from McKay Ditch and No Name Gulch were carrying activity to GS03, it would be expected that levels of activity would correlate with runoff.

Though there is evidence to suggest that the contaminated water observed at GS03 did not originate as contaminated water in the major tributaries, it remains possible that the tributaries contribute contamination in the form of solids to the Walnut Creek drainage. For example, some of the higher historical soil sample activities were measured below the Landfill Dam on No Name Gulch, and these soils may be transported during some runoff events. However, results from the August 21, 1997 sediment sampling along Walnut Creek (see Section 3.3 in Progress Report #2) do not indicate significant spatial trends in sediment activity that show contaminated sediment loads from these tributaries. Also, two new Source Location monitoring stations were installed on these tributaries just upstream from their confluences with Walnut Creek (GS33 on No Name Gulch and GS35 on the McKay Ditch; Figure 2-1). These locations are equipped to collect continuous flow-paced composite samples and gage stream flow which will be used in loading calculations. To date, both GS33 and GS35 have collected two samples with low activities (see Table 4-2). Additionally, GS34 has been installed on Walnut Creek just upstream of the McKay Ditch confluence to provide increased loading resolution. To date no samples have been analyzed from GS34. Water-quality data from these locations will be very valuable should another exceedance occur at GS03.

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5.3. SURFACE-WATER ACTIVITY VARIABILITY AND OCCURRENCE OF SMALL CONTAMINATED PARTICLES

It is possible that the recent elevated measurements at GS03 are an indication of the variability of radionuclide concentrations in surface water. Previous sampling protocols, having not used a continuous monitoring approach, may not have accurately characterized the true variability of surface-water activities. Current sampling protocols (see discussion in Section 6.2.4 in Progress Report #1; implemented October 1, 1996) have dramatically increased the number of grab samples collected at GS03, and consequently the likelihood of capturing occasional small particles with relatively high specific activity (also sometimes referenced in the technical literature as "hot" particles).

The change in sampling protocol (instituted in October 1996) brings into question whether the recent 'elevated' measurements at GS03 represent deviations from the historical average or norm. In previous years, perhaps 50-100 grab samples were collected at this location. Under the continuous flow-paced protocols, some 2,500 grab samples may be pulled in a given year depending on location (1,267 grab samples were collected at GS03 in WY97, 855 grabs to date for WY98). Table 5-3 and Figure 5-2 show the high variability of low-level radionuclides in Site surface waters (variability at locations other than GS03 is provided in for reference).

Table 5-3. Summary Statistics for Pu at Selected Site Monitoring Locations.

Monitoring Location	Mean Pu Activity (pCi/l)[a]	Max Pu Activity (pCi/l)
GS03	0.016	0.465
GS10	0.199	1.91
SW093	0.251	5.30
GS27	18.1	90.0

a Arithmetic average.

It is possible that sampling protocols prior to the continuous flow-paced sampling under RFCA underestimated the actual variability of surface-water activities. The current RFCA sampling protocols were developed, using the DQO process, to representatively measure water quality. Figure 5-3 demonstrates qualitatively the potential effects that different sampling frequencies can have on measured activity. Assuming that activities in surface water are highly variable, then a small number of grabs (N=5 in the top of Figure 5-3) for a composite sample underestimates the 'true' surface-water activity, when the grab samples were randomly collected during periods of relatively lower activities. Similarly, a significant increase in the number of sample grabs (N=10 in the bottom of Figure 5-3) would be more likely to capture infrequent higher activity outliers (e.g., toward the right side of Figure 5-2) and accurately represent the 'true' activity. Therefore, the increased monitoring under RFCA may be more representatively measuring the surface-water activities. Implications of this improved monitoring protocol are unclear without data from additional water years, but may indicate that future exceedances of the existing standard may occur. However, the expected recurrence of these exceedances can not be quantified at this time.

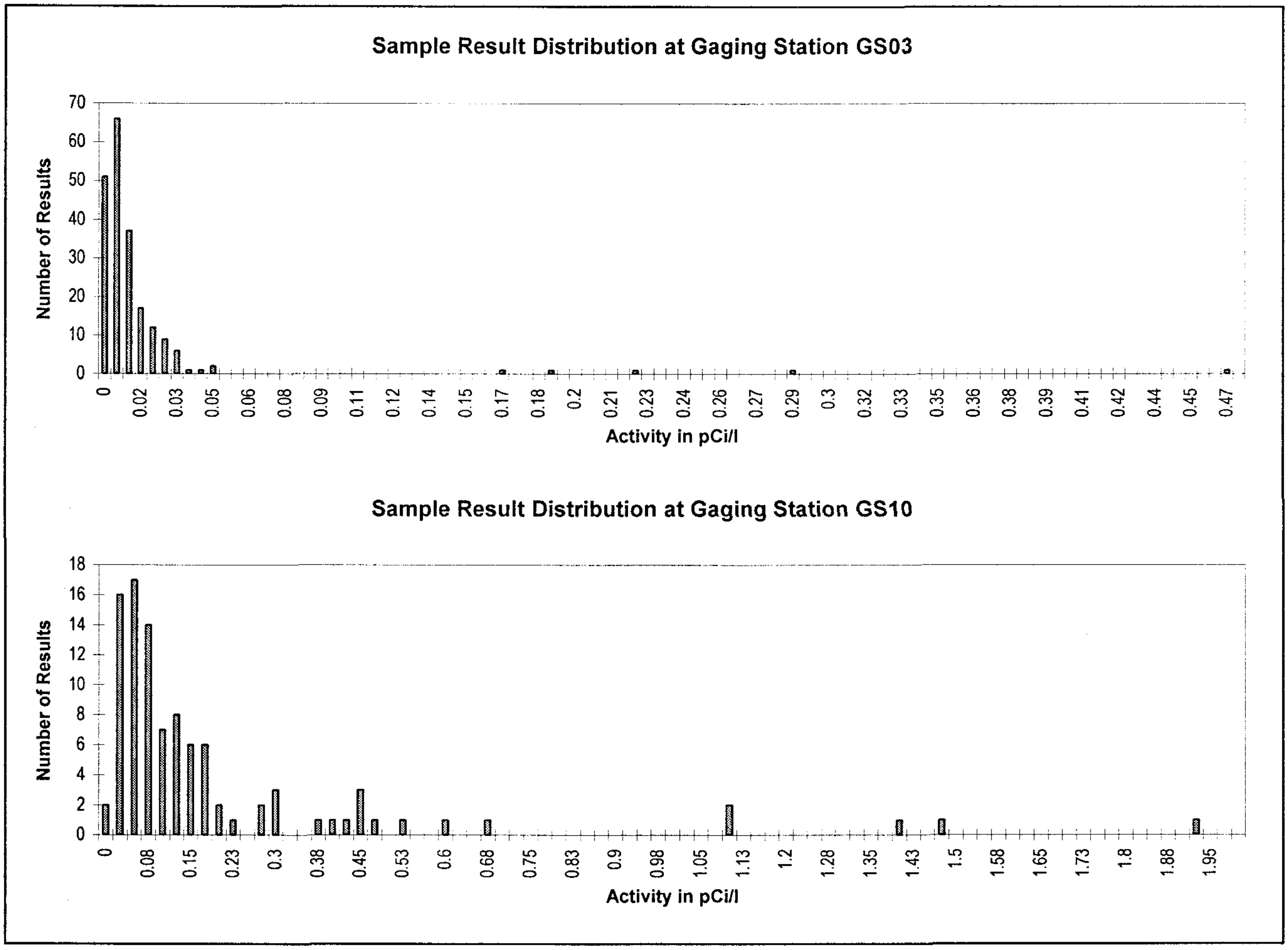

Figure 5-2. Sample Result Distribution at Gaging Stations GS03 and GS10.

This variability in measured surface-water activities can be influenced by many factors including:

- Spatial variation in the activity of the source soils which are transported to surface water;
- Spatial variation in precipitation patterns which determines the generation of eroded material and suspended solids;
- Hydrologic characteristics of storm events (snowmelt patterns, overland flow patterns, raindrop impact variations due to storm intensity, etc.) which influence solids transport;
- Stream flow characteristics influencing suspension and settling of solids as well as turbulent scouring of channels;
- Ongoing erosion of Site soils / sediments;
- Environmental variations of physiochemical or biochemical factors which may influence transport of actinides; and

- Physical and chemical characteristics of actinides in the environment such as speciation and the occurrence of discrete particles with high specific actinide content , or 'hot particles'.

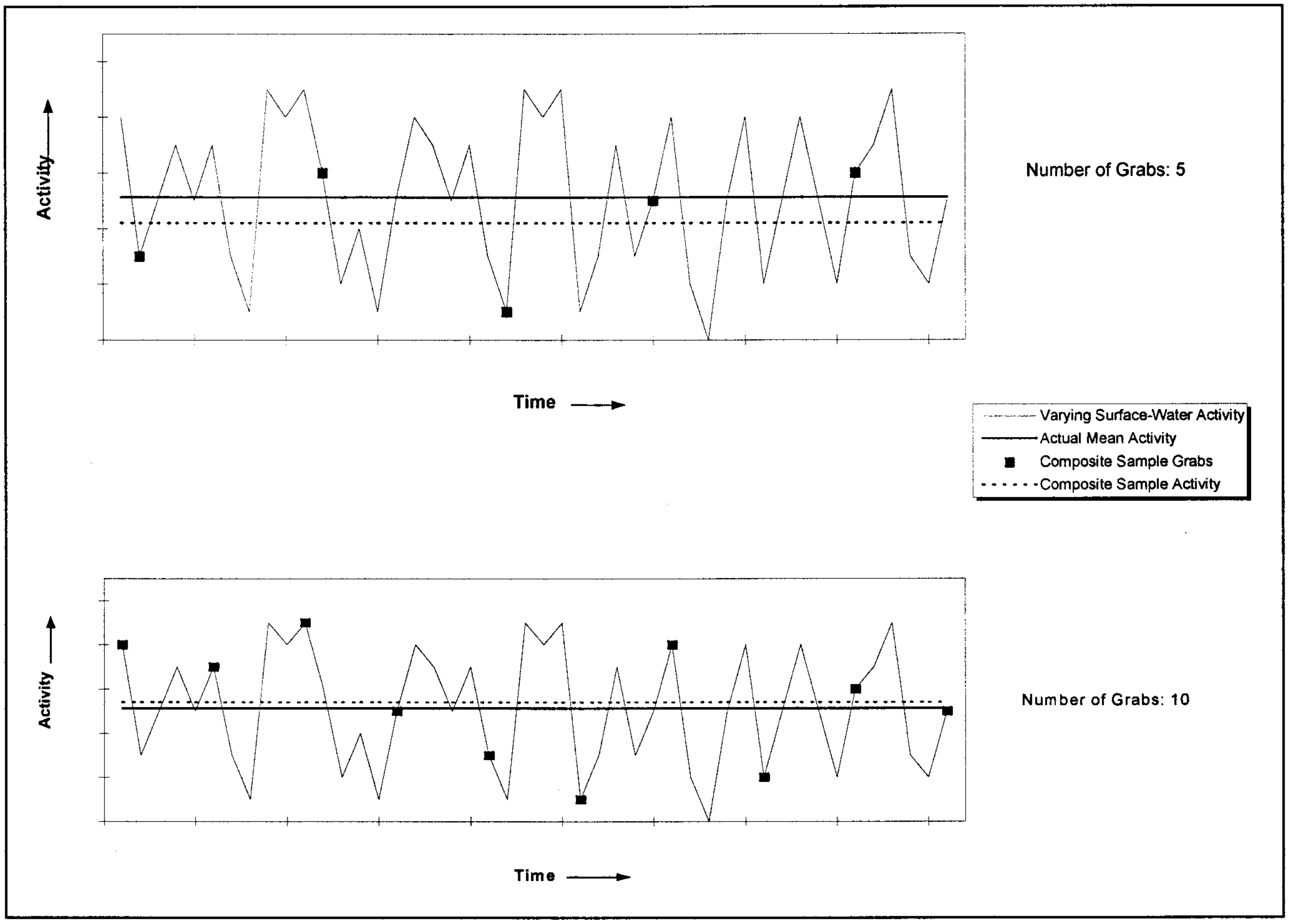

Figure 5-3. Hypothetical Effects of Sampling Protocols on Measured Surface-Water Activities.

Several studies at the Site have documented the nature and extent of the discrete Pu particle phenomenon in the soils of RFETS.[19,20] Table 5-4 shows that small quantities (i.e., submicron-sized particles) of plutonium oxide (PuO_2) could result in activities that would challenge the Site standard of 0.15 pCi/l Pu. Also, if it is assumed that there is some distribution of these particles such that availability of relatively larger particles is relatively uncommon, results for measured surface-water activities could be variable. Similarly, a

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[19] Little, C. A. et al., 1980, "Plutonium in a Grassland Ecosystem at Rocky Flats," *Journal of Environmental Quality*, Vol. 9 no. 3 July - September 1980, pp. 350-354.

[20] Liataor, M. I. et al., 1996, "Fate and Transport of Plutonium-239+240 and Americium-241in the Soil of Rocky Flats, Colorado" *Journal of Environmental Quality*, Vol. 25 July - August 1996.

significant increase in grab sampling frequencies would increase the probability of obtaining one of these 'hot particles' in a composite sample.

Table 5-4. Mean PuO_2 Particle Diameter Versus Activity.*

Mean Particle Diameter (μm)	Activity (pCi)/Particle**	Particles to Equal 0.15 pCi
0.1	0.00044	342
0.25	0.0069	21
0.4	0.028	6
0.5	0.055	3
1.0	0.44	< 1

* Taken from "Workplan for the Control of Radionuclide Levels in Water Discharges from the Rocky Flats Plant", Manual No. 2100-WP-12501.1, January 1992.
** Calculation uses a density of 11.5 grams per cubic centimeter (g/cm^3) and a specific activity of 0.073 curies per gram (Ci/g) for RFETS PuO_2.

Consultation with the AMS Scientists and the DQO Statisticians is ongoing regarding these sampling protocol effects. Planned FY98 AMS activities (see Section 11.4) evaluating fractionation of TSS in surface-water and speciation/characterization of the associated Pu should provide additional insight into the transport of Pu in Site surface waters.

5.4. POTENTIAL ISSUES WITH LABORATORY RESULTS

Issues with the quality of analytical laboratory results must also be considered when interpreting off-normal radioanalytical data. Variations in analytical data from historically observed results at GS03 naturally cause reevaluation of results from a data quality perspective. Factors to consider which might contribute to variation include changes in sample collection protocols (flow-paced composites vs. grabs, as previously described), use of newly subcontracted analytical labs (three sub-contracted labs have been used since December 1995 versus one on-site lab), variability in sample preparation and handling (currently, one subcontracted staff person is assigned to RFCA sample preparation and handling), and general analytical variability for radiochemistry samples at or near the level of detection. All subcontracted labs are required to perform to the same quality standard and should therefore produce the same quality data. Lab-to-lab variability, especially for the low-level radionuclide measurements, may be one of the more likely sources of sample result variability.

All data that contributed to the exceedance at GS03 were validated under criteria established by the Site and found to be valid. Data validation, as described in the Site's *General Guidelines for Data Verification and Validation*, DA-GR01-v1, 12/3/97, is a process designed to determine the extent to which the subcontract laboratory accurately and completely reported all sample and quality control results and their adherence to the specific Module contractual requirements. Validation does not assess or measure the variability that laboratories may introduce as part of their unique analytical processes. Factors such as laboratory staff experience, ambient laboratory conditions, and variation in analytical methods, as well as method-specific variability can, and do, contribute to sample result variability, especially at the very low radioactivity levels being measured. Low sample volume, such as that of the composite sample collected from GS03 over the period of May 15, 1997 through June 25, 1997, can also challenge the accuracy of the results. As long as all data are reported accurately and the specific Module requirements, such as detection level or sample preparation, are met, then data are considered valid. The change from Site analytical laboratories, which had demonstrated good analytical comparability at environmental levels of radionuclides of interest, to off-site commercial laboratories may have introduced a measure of analytical variability that cannot be accurately assessed. These laboratories were originally contracted because the single laboratory was not capable of handling the large number of samples routinely collected for analysis. The availability of multiple subcontracted laboratories also provides alternatives in the event that one laboratory cannot perform analyses due to any number of problems such as equipment failure. The use of periodic, Site-prepared blind samples to test laboratory accuracy is currently being considered.

6. DATA SUMMARY AND ANALYSIS FOR GS10

Progress Report #2 primarily included analysis and interpretation of environmental information for the GS10 drainage. New information collected since Progress Reports #2 and #3 is included in the following section. A cross-referenced discussion of this information and the specific source location hypotheses they support (or not) are included in Section 7.

6.1. AUTOMATED SURFACE-WATER MONITORING DATA

This section presents data summary and analysis for environmental information collected at gaging stations GS10 (S. Walnut Creek above Pond B-1) and upstream tributary locations SW022 (Central Ave. Ditch at Inner East Gate), GS27 (ditch NW of B884), GS28 (ditch NW ofB865), GS37 (Central Ave. Ditch N of B443), GS38 (Central Ave. Ditch at 8th St.), GS39 (ditch N of 904 Pad), and GS40 (S Walnut Cr. E of 750 Pad) as shown in Figure 6-1.[21] Data presented include flow rates, discharge volumes, radionuclide activities, radionuclide loads, and water-quality parameters. Analysis was performed on averages of all data available from WY93 to present, the continuous flow-paced samples from WY97, and the periods of WY98 that are available[22,15]. Although both Pu and Am were elevated at GS10, for simplicity this section focuses on the transport and source location for Pu only.

6.1.1. Data Summary

Significant data exists for flow and radionuclide activities at the gaging stations of interest. Information for TSS, metals, major ions, etc. is more limited. Additional information for these parameters may need to be collected if the progress of the ongoing source evaluation demonstrates the need for additional data to draw definite conclusions. Individual results are averages of target, duplicate, and replicate results for each sample. Results which were rejected through the validation process are not included. All activities are for total radionuclides and negative results were set to zero for calculation purposes.

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[21] Source Location stations (GS38, GS39, GS40) were installed in response to the exceedances measured at GS10 as part of the source evaluation.

[22] Flow data is included for the period 10/1/92 - 2/28/98; analytical data is included for the period from 10/1/92 - 2/28/98, where available from the labs.

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Surface-Water Flow Rates and Discharge Volumes

A reliable flow record has been collected at GS10 since WY93. Flow record has been collected at SW022, GS27, and GS28 since the Spring 1995. Monitoring was terminated at GS28 in August 1997 after this location had completed its Performance Monitoring requirements. Flow measurement began at GS37, GS38, GS39, and GS40 on October 27, 1998, January 27, 1998, January 15, 1998, and March 3, 1998 respectively. Flow data included in this Final Report ends on February 28, 1998. Due to the limited flow data for GS37-GS40, these stations will not be included in the discharge analysis at this time. Relative average annual discharge percent to GS10 for SW022, GS27, and GS28 is 30%, 0.29%, and 1.06% respectively. However, during very high runoff events, the Central Avenue Ditch overflows through a corrugated metal pipe directly to GS10, short-circuiting SW022 (see Figure 3-1). Consequently, discharge and load associated with the Central Avenue Ditch drainage will be slightly underestimated in the following analysis. Variation of flow rates and discharge volumes is significant at GS10, and coincides with variation in precipitation (as indicated by Figure 6-2 and Figure 6-3). Baseflow at GS10 is continuous and near constant year-round.

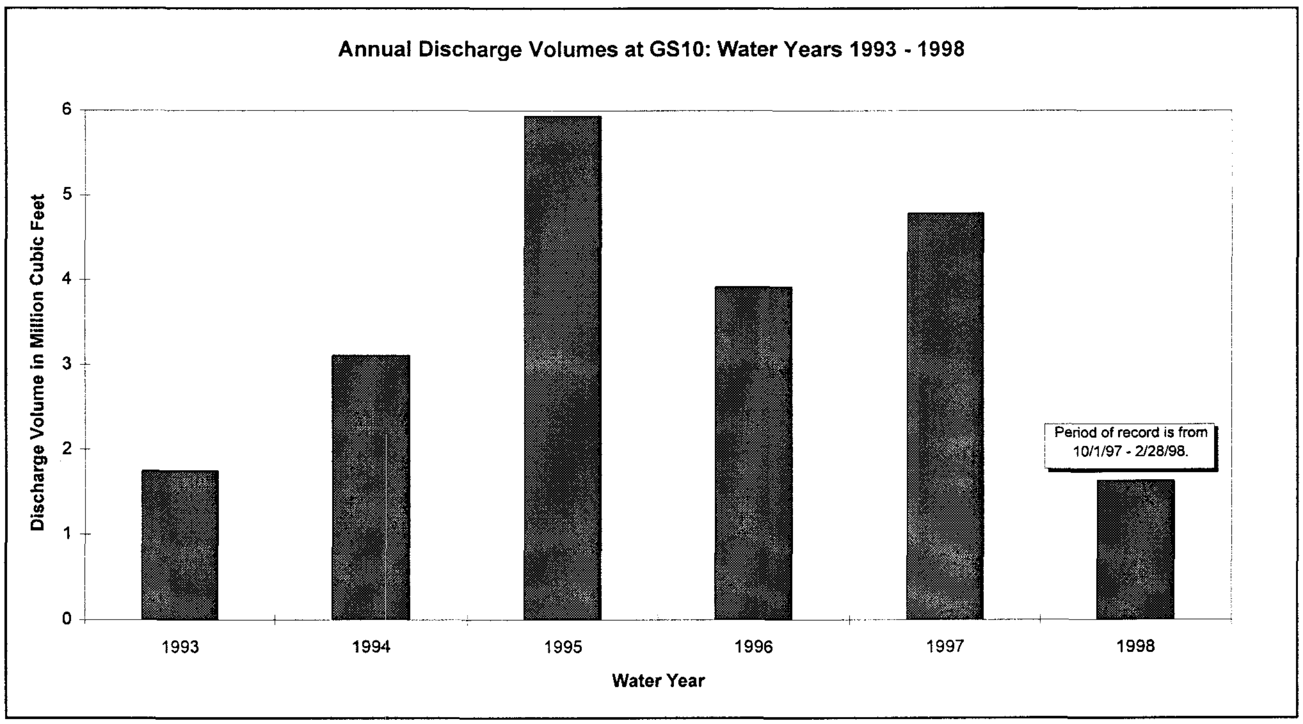

Figure 6-2. Annual Discharge Volumes for GS10.

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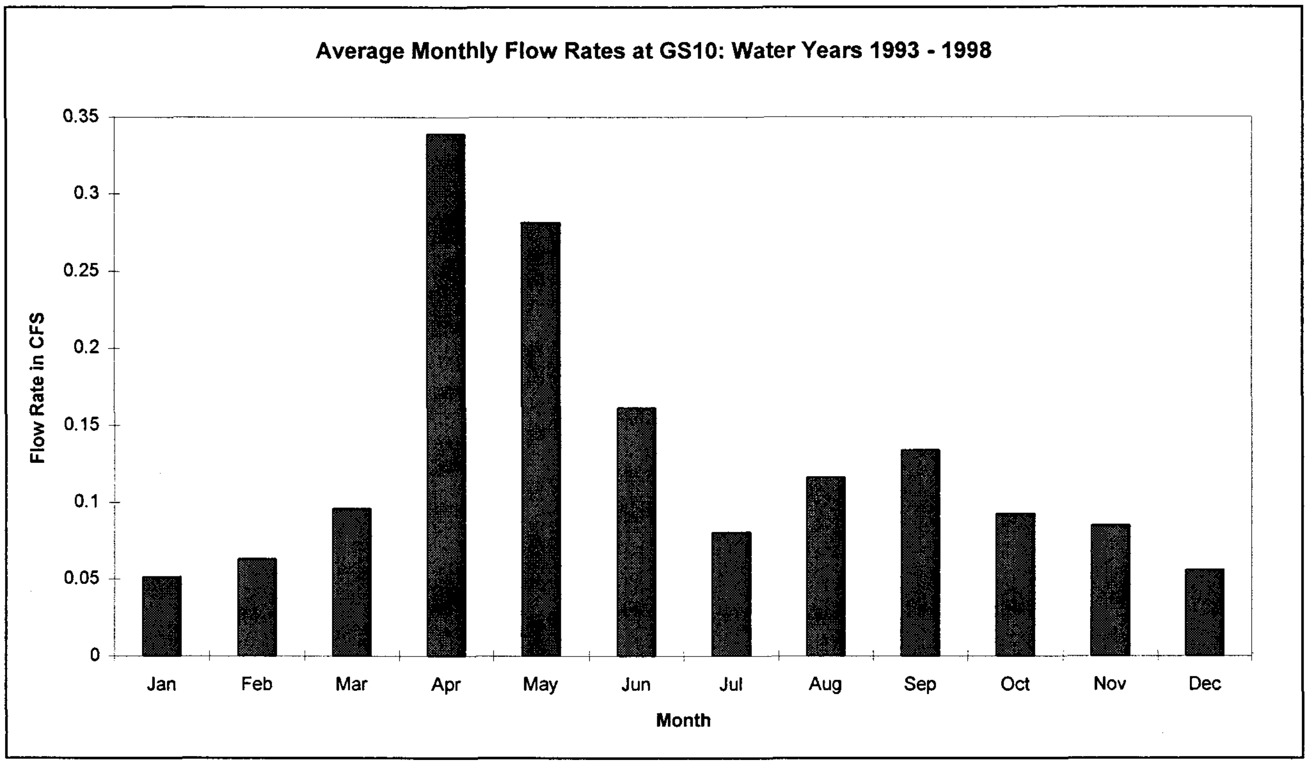

Figure 6-3. Average Monthly Flow Rates at GS10.

Radionuclide Activities

Individual analytical results for Pu at the gaging stations of interest are shown in Figure 6-4 through Figure 6-6. All sample results are plotted regardless of sampling protocol employed[23]. The large variation in activities is evident in these plots. Inspection of statistical means and standard deviations calculated for a log-normal (transform of the) data for GS10 indicate that the highest recorded Pu activity at GS10, 1.91 pCi/l, is more than 2 standard deviations from the mean. A log-normal distribution represents a much better approximation of the actual data distribution than a normal distribution.

Summary statistics for these results are shown in Table 6-1. These activities are arithmetic averages, which do not take into account the hydrologic conditions during sampling (storm-event, baseflow, etc.), the flow rate (more importantly, the discharge volume), or the sampling protocol.

[23] Individual grabs, time-paced (scheduled grabs) composites, storm-event (hydrograph rising limb) flow-paced composites, and continuous flow-paced composites are shown. For a discussion of sample collection methods, see Section 6.2.4 in Progress Report #1.

Table 6-1. Summary Statistics for Samples from Gaging Stations in GS10 Drainage.

Sampling Location	Number of Samples	Average[b] Activity (pCi/l)	Maximum Result (pCi/l)	Standard Deviation[c] (pCi/l)
GS10				
WY93 - WY98	87	0.199	1.910	0.331
SW022				
WY95 - WY98	23	0.462	6.0	1.246
GS27[a]				
WY95 - WY98	19	18.1	90.0	27.17
WY95 - WY96	10	31.895	90.0	32.053
WY97 - WY98	9	2.77	6.19	1.584
GS28				
WY95 - WY97	15	0.252	0.852	0.291
GS37				
WY98	1	0.00	0.00	NA
GS38				
WY98	0	NA	NA	NA
GS39				
WY98	1	0.034	0.034	NA
GS40				
WY98	0	NA	NA	NA

[a] Periods are broken out due to GS27 drainage changes in WY96; see details in text discussion below
[b] Arithmetic average
[c] Assumes normal distribution for simplicity.

At gaging station SW022, as shown in Figure 6-5, a sample with an activity of 6.0 pCi/l Pu was collected on August 4, 1997 when the Site received approximately 1.2 inches of precipitation in less than 30 minutes. This event resulted in peak flow rates at GS10 of approximately 50 cfs. This result at SW022 is nearly an order of magnitude larger than previous measurements at SW022.

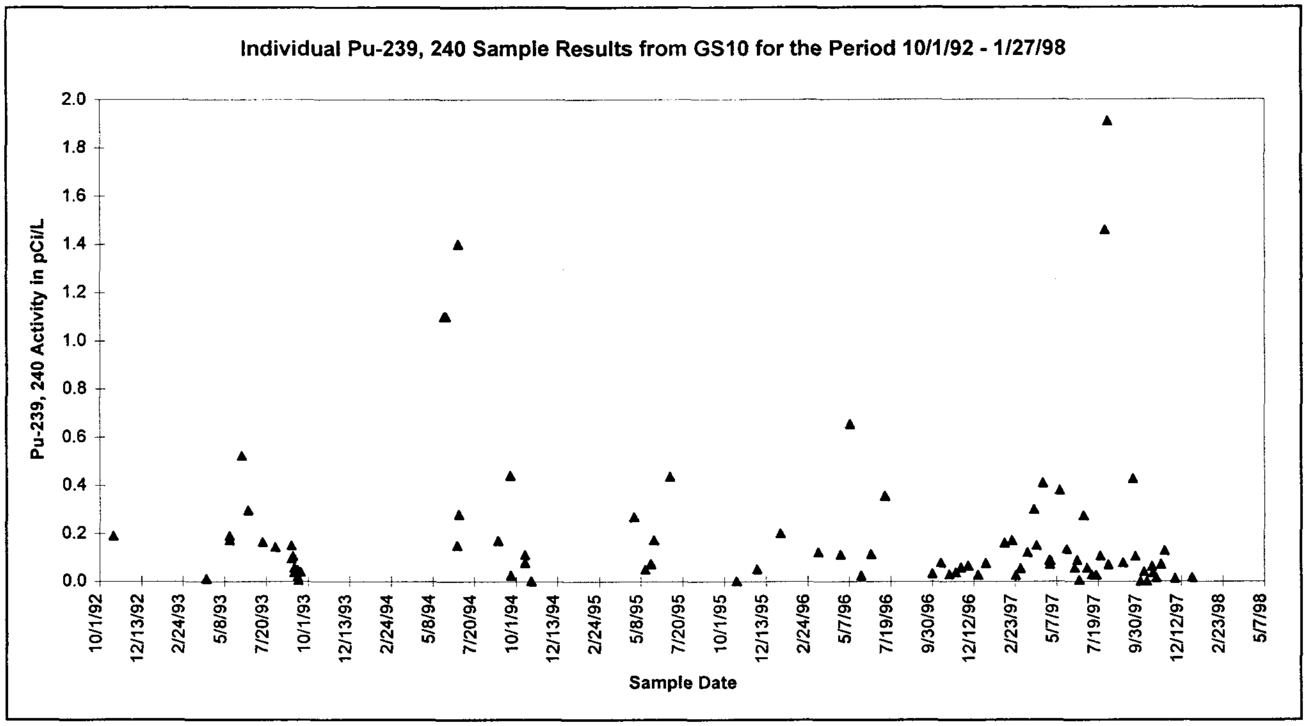

Figure 6-4. Individual Analytical Pu Results for GS10.

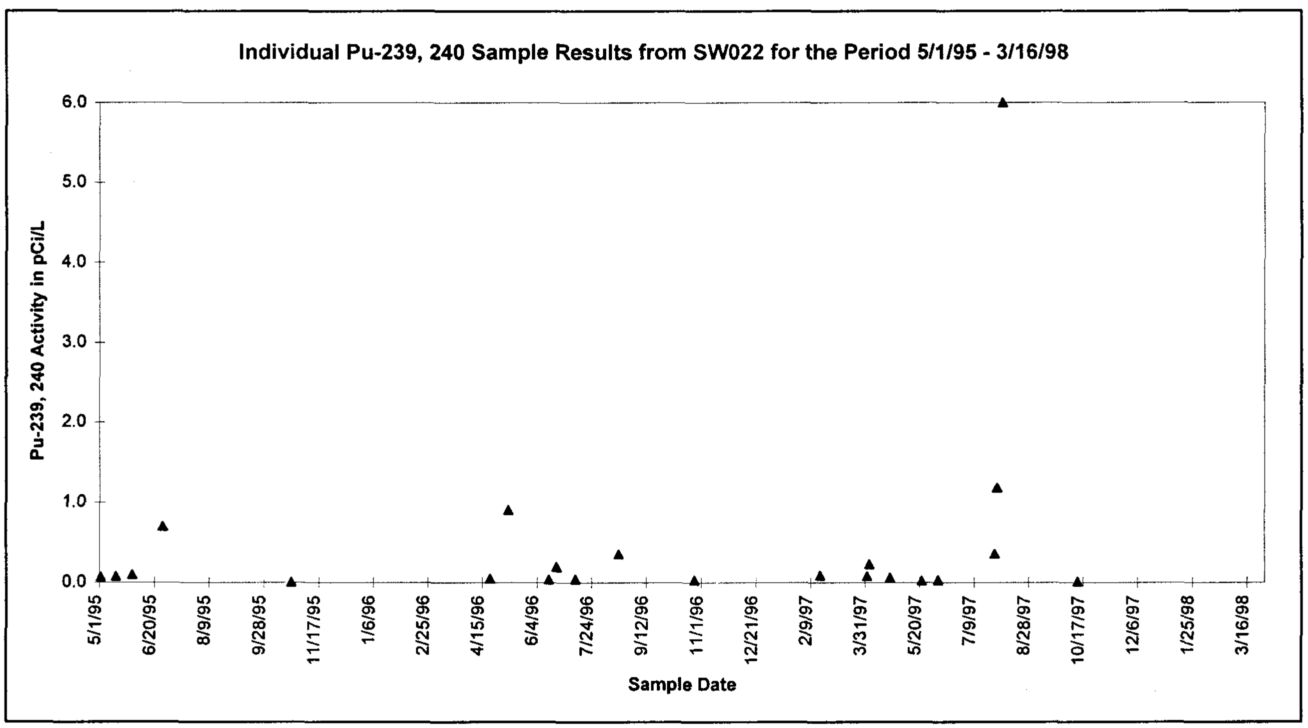

Figure 6-5. Individual Analytical Pu Results for SW022.

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The 90 pCi/l activity (TSS of 1,650 mg/l) at GS27 (Figure 6-6) is the highest activity measured to date by the automated monitoring network for stormwater runoff at the Site. Several other samples were also in the 30 to 75 pCi/l range. GS27 is a Performance Monitoring location originally installed to support the B889 D&D project. Samples were collected before, during, and after the D&D of B889. The drainage basin is approximately 1 acre of pavement and exposed soils. The high activities prompted the Site to initiate an investigation, with the intent being the mitigation of contaminated soils or the removal of a 'hot spot'. Soil activities in the area range from 0.1 to 10 pCi/g. Measured TSS concentrations at this location range from 12 to 1,650 mg/l. If it is assumed that the Pu is associated with soil and surface-water TSS on a strictly mass to mass ratio, runoff with 1,650 mg/l of TSS and Pu activity of 90 pCi/l would indicate a soil activity of 56 pCi/g in the GS27 drainage. This level of soil activity far exceeds any value measured in the GS27 basin. This indicates soil suspension in runoff may not be uniform, and that the particles most associated with Pu may be preferentially suspended and transported in surface-water runoff.

Consequently, some soil was removed from the drainage ditch immediately upstream of GS27, and exposed soils were treated with a soil stabilizer called Topseal®. Additionally, the D&D and removal of B889 was completed at the end of WY96. A significant change between WY95-WY96 and WY97 sample Pu activities at GS27 can be seen in Table 6-1 and Figure 6-6. The relatively lower activities measured in WY97 are likely a direct result of the completed mitigation projects. Additionally, WY97 TSS values for similar flow magnitudes show a slight decrease. Further discussion on GS27 is contained in Section 4.3 of Progress Report #2 and Section 9.4 of Progress Report #3.

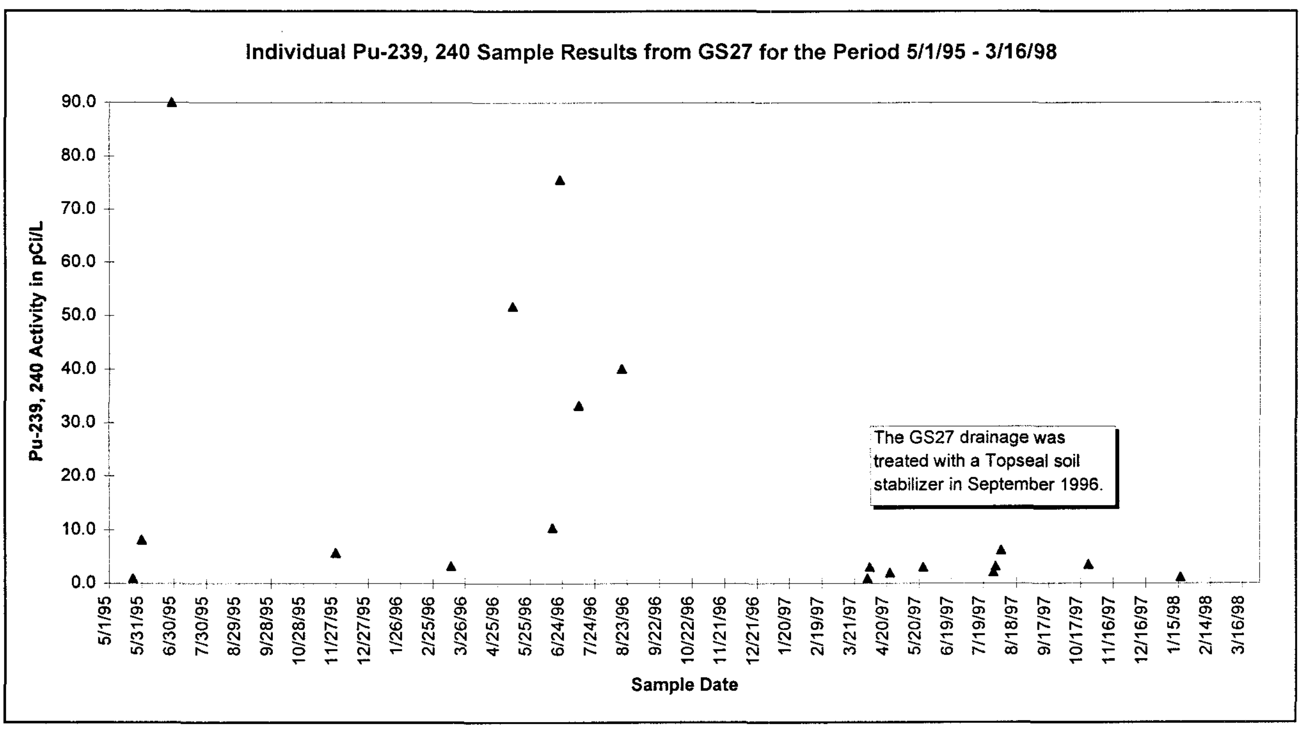

Figure 6-6. Individual Analytical Pu Results for GS27.

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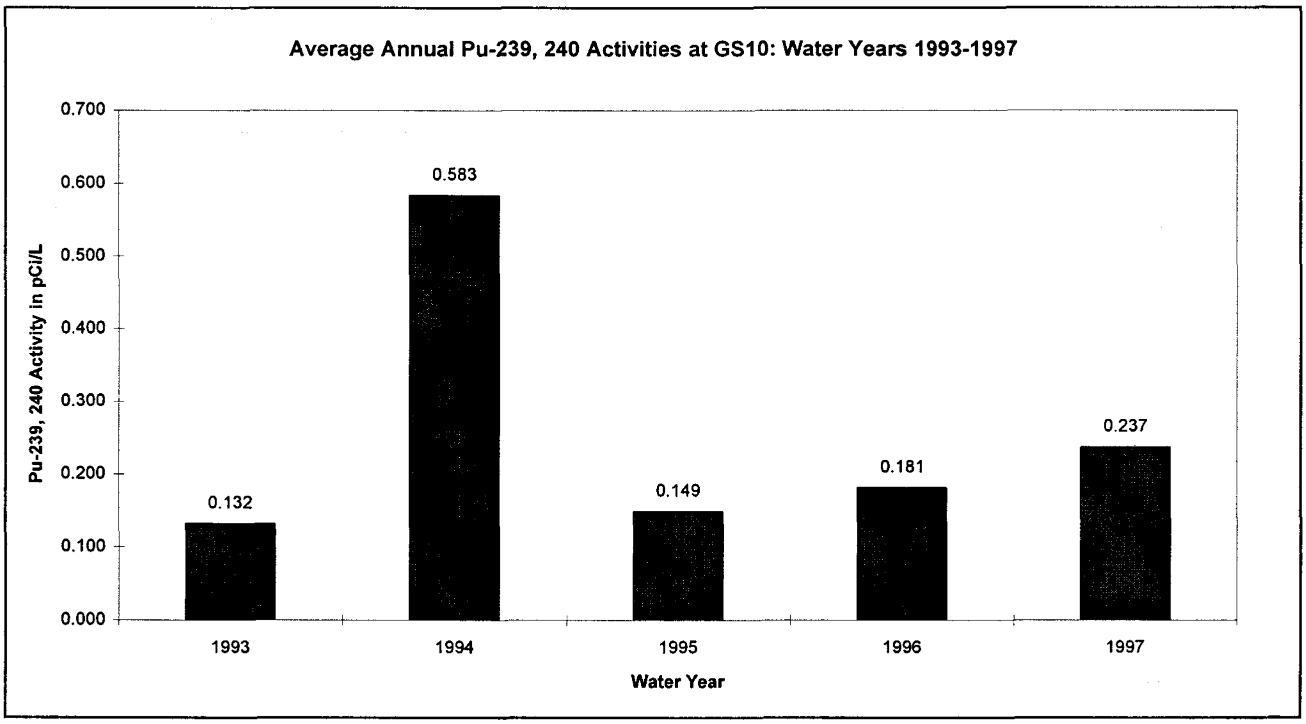
Figure 6-7 shows the average annual activities at GS10 for WY93 - WY97. For WY93 - WY96, arithmetic averages are plotted. However, due to the continuous flow-paced sampling protocols currently in place, the more representative volume-weighted average activity is shown for WY97. This WY97 volume-weighted average is calculated in a fashion similar to 30-day averages[5], except that the period is for the water year.[24] It is important to note that although elevated measurements were made in WY97, the volume-weighted average is comparable to the activities for other years.

It is generally agreed that Pu tends to form strong associations with particulate matter. If contaminated particles are transported in surface water, then the observed Pu levels could be correlated with the amount of TSS. The data collected at GS10 is a good example (Figure 6-8) of this phenomenon. During high intensity precipitation events, with increased raindrop impact, higher quantities of solids are transported in overland flow. Similarly, higher flow rates in ditches and creeks, generally result in increased TSS values due to higher flow velocity and turbulence. Figure 6-9 shows monthly arithmetic average activities which increase for months with higher rainfall and flow rates which are shown on Figure 6-3. The high activities for the month of August were measured during runoff from the intense monsoon-related precipitation on July 30, 1997 through August 6, 1997.



Volume-weighted average is plotted for WY97.

Figure 6-7. Average Annual Pu Activities for GS10.

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[24] Each carboy has a load in pCi calculated from the activity and the associated creek discharge volume. The total load in pCi for all samples is then divided by the total creek discharge volume to give the volume-weighted activity in pCi/l.

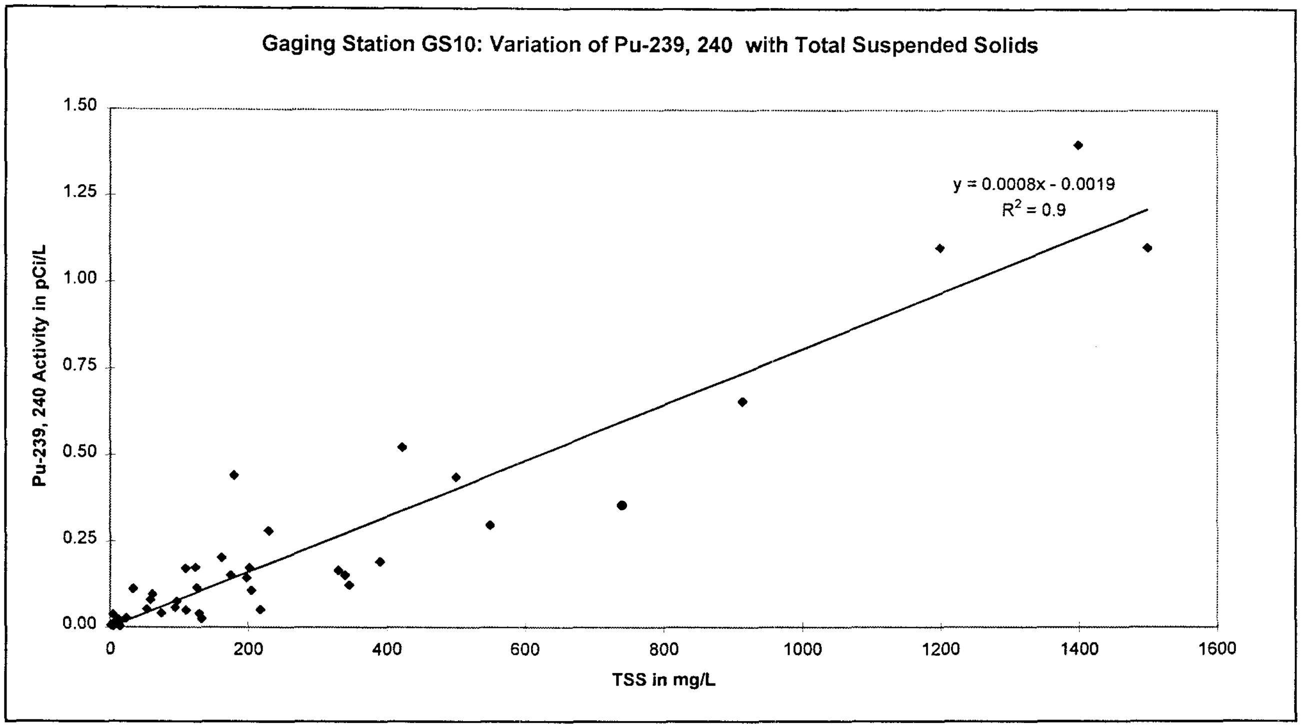
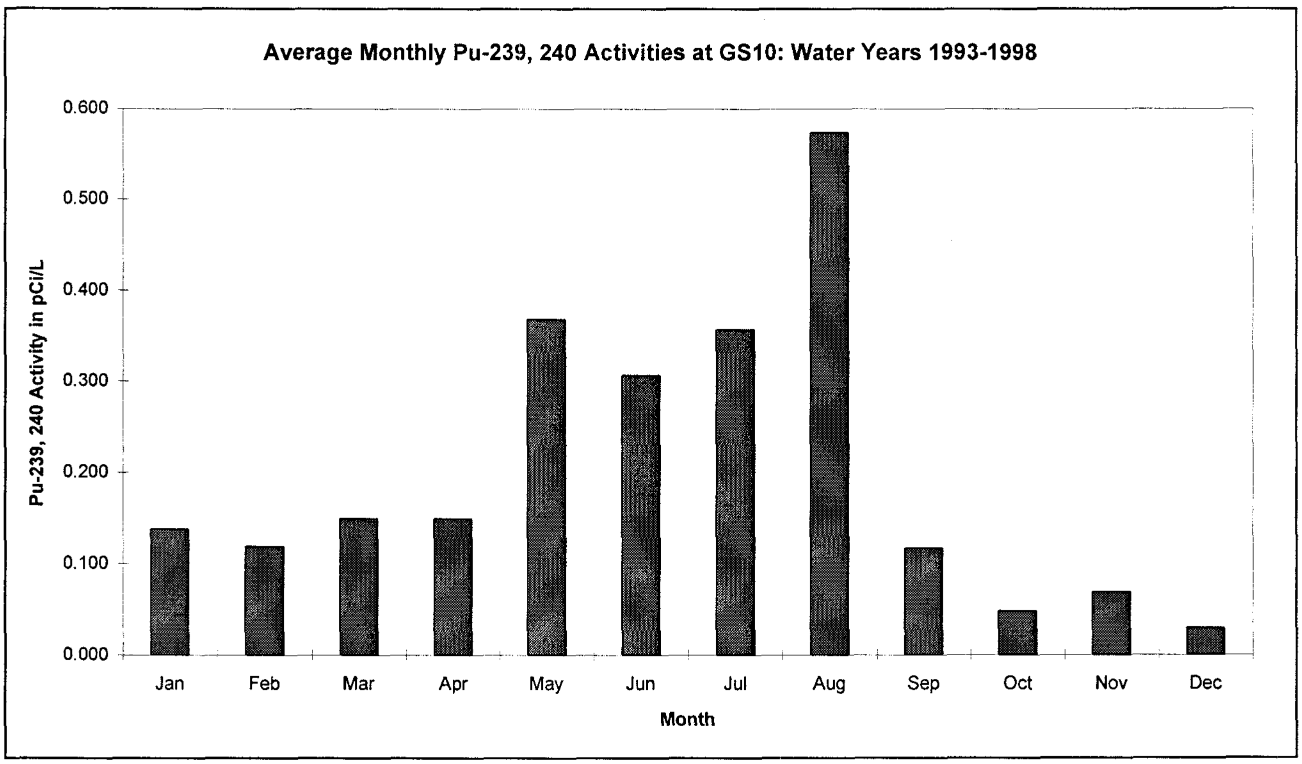


Figure 6-8. Variation of Pu with TSS at GS10.



All averages are arithmetic.

Figure 6-9. Average Monthly Pu Activities at GS10.

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6.1.2. Loading Analysis

This loading analysis will include gaging stations GS10, SW022, GS27, and GS28. Performance monitoring location GS37 and Source Location monitoring stations GS38, GS39, and GS40 will not be included at this time due to the limited number of samples collected to date (see Table 6-1). These locations will be included in future loading calculations as part of the increased monitoring scope the Site has undertaken. Incorporation of loading data from the three Source Location stations will help to quantify loads from the corresponding subbasins contributing to GS10. These calculations will define the loads from each subbasin to indicate general location of discrete sources or to support the hypothesis of a distributed diffuse source.

WY93 - WY98 Monitoring Data

Annual loads for GS10 in micrograms are plotted in Figure 6-10. For WY93 - WY96, the arithmetic average activity is multiplied by the associated total annual discharge volume, then converted to micrograms. For WY97, the activity for each flow-paced composite is multiplied by the associated discharge volume, then converted to micrograms and totaled. Figure 6-10 shows the relative magnitude of WY97 loads compared to previous water years.

Loading for various sub-drainages tributary to GS10 was estimated by multiplying the arithmetic average Pu activity at the gaging stations (which define the sub-drainages) by the corresponding average annual discharge for each gage. Figure 6-11 shows that the small GS27 sub-basin may contribute approximately 37% of the Pu load reaching SW022. However, other basins contributing to the Central Avenue Ditch, including the 903 Pad, contribute approximately 61% of the Pu load. This gain indicates that Pu entered Central Avenue Ditch from areas other than those monitored by GS27 and GS28.

Figure 6-12 shows that the small GS27 sub-basin may contribute approximately 29% of the Pu load reaching GS10. However, watershed improvements have significantly reduced the contribution from this sub-basin, as discussed below in the analysis solely for WY97 data. Figure 6-12 also indicates that sub-basins along the south side of the Protected Area (PA), which flow directly to GS10, contribute approximately 23% of the Pu load. These loading distributions indicate that there are multiple Pu sources contributing to GS10.

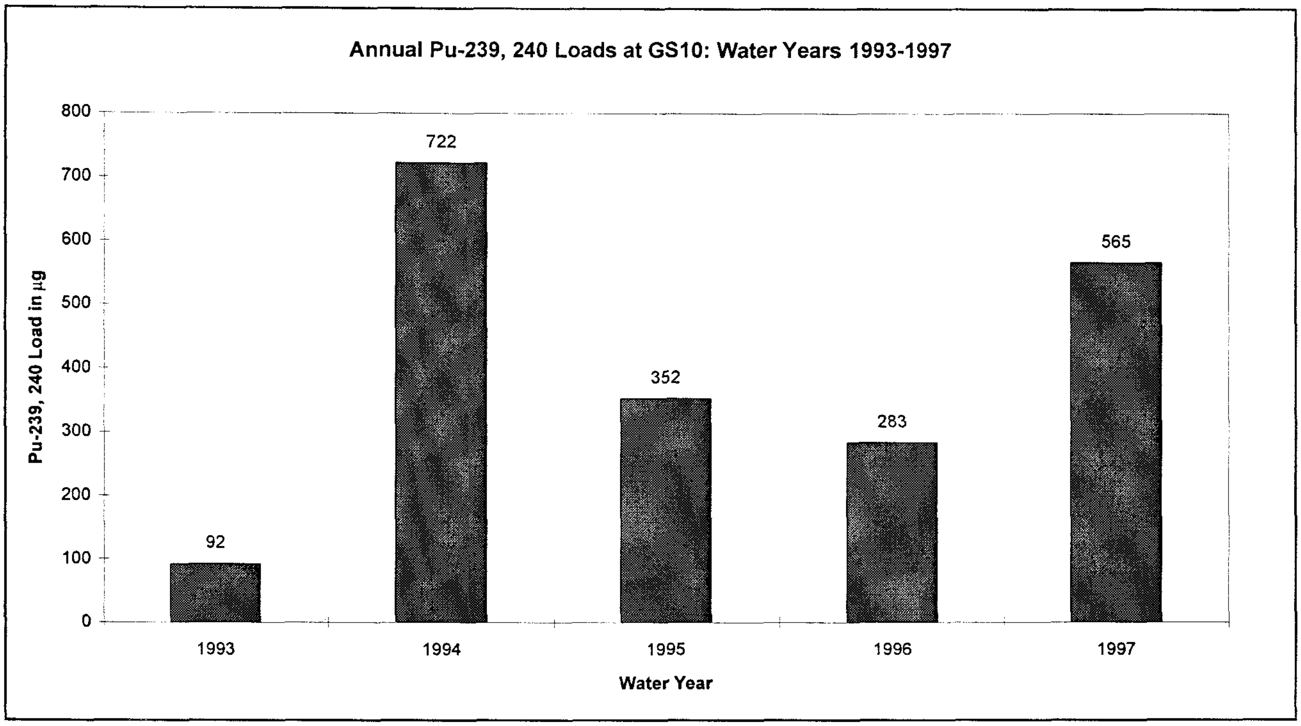

Figure 6-10. Annual Pu Loads at GS10.

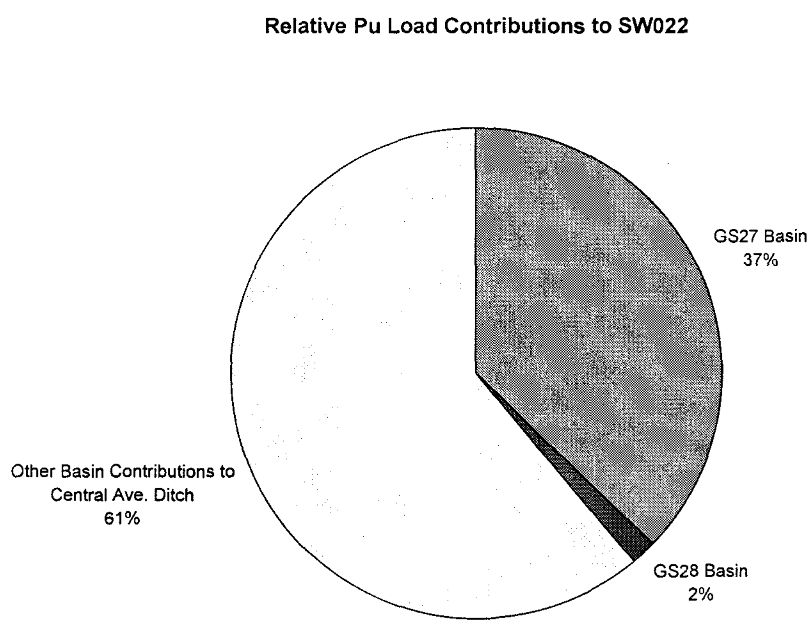

Figure 6-11. Relative Sub-Basin Loads to SW022: WY93-WY98.

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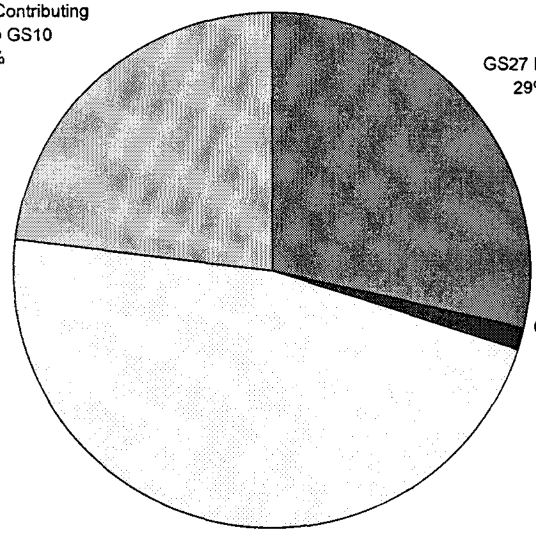

Figure 6-12. Relative Sub-Basin Loads to GS10: WY93-WY98.

WY97 and WY98 Continuous Flow-Paced Monitoring Data

Figure 6-13 shows volume-weighted average monthly activities for continuous flow-paced samples collected in WY97 and WY98 at GS10. Analytical results are available through January 27, 1998. The upward trend is likely due to seasonal hydrologic (more intense runoff), chemical, and biological variations which may result in the increased mobility of Pu.

Detail for each continuous flow-paced composite sample for WY97 and WY98 at GS10 is presented in Table A-10. Elevated samples are indicated in bold. Detail for each flow-paced storm-event composite sample from SW022, GS27, and GS28 is presented in Table A-11. It is important to note the highly variable activity for the samples. It is apparent that the variability of surface-water activity, and the transport mechanisms for Pu are not fully understood. Variations in intensity of precipitation events, with increased raindrop impact, could result in varying quantities of solids transported in overland flow. Similarly, variable flow rates in ditches and creeks generally result in variable TSS values due to varying flow velocities and turbulence. Additionally, seasonal changes in biological and chemical processes may influence Pu transport.

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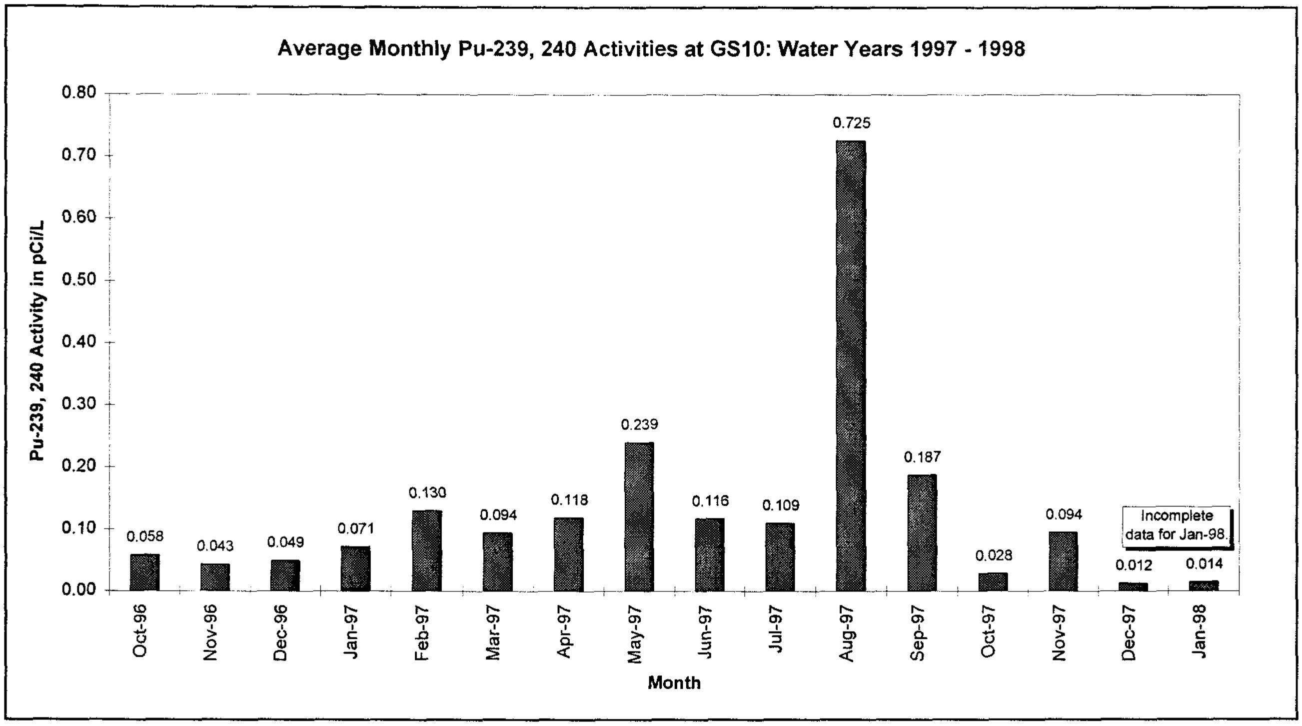

Figure 6-13. Average Monthly Pu Activities for WY97-WY98 at GS10.

Prior to WY97, all locations collected flow-paced storm-event samples. Beginning in WY97, continuous flow-paced samples were collected at GS10, while flow-paced storm-event samples were collected at SW022, GS27, and GS28. WY97-WY98 loading analysis for various sub-drainages tributary to GS10 was estimated by multiplying the arithmetic average Pu activity at the gaging stations (SW022 and GS27 which define the sub-drainages; GS28 was not included due to discontinuation of monitoring in WY98) by the corresponding average annual discharge for each gage. For GS10, the activity for each flow-paced composite is multiplied by the associated discharge volume, then converted to micrograms and totaled (Table A-10). Figure 6-14 shows that the small GS27 sub-basin contributed approximately 3% of the Pu load reaching SW022, a significant decrease from previous years after watershed improvements. However, other basins contributing to the Central Avenue Ditch, including the 903 Pad, contribute approximately 97% of the Pu load. This gain indicates that Pu entered Central Avenue Ditch from areas other than those monitored by GS27. Gaging stations GS37, GS38, GS39, and GS40 will provide additional loading resolution to determine relative loads from each gage's corresponding subbasin.

Figure 6-15 also indicates that sub-basins along the south side of the PA, which flow directly to GS10, contribute approximately 27% of the Pu load. Figure 6-15 also indicates that the southern Industrial Area feeding the Central Avenue Ditch is a significant source, indicating the need for the additional Source Location monitoring stations GS38, GS39, and GS40. These loading distributions also indicate that there are likely multiple Pu sources contributing to GS10.

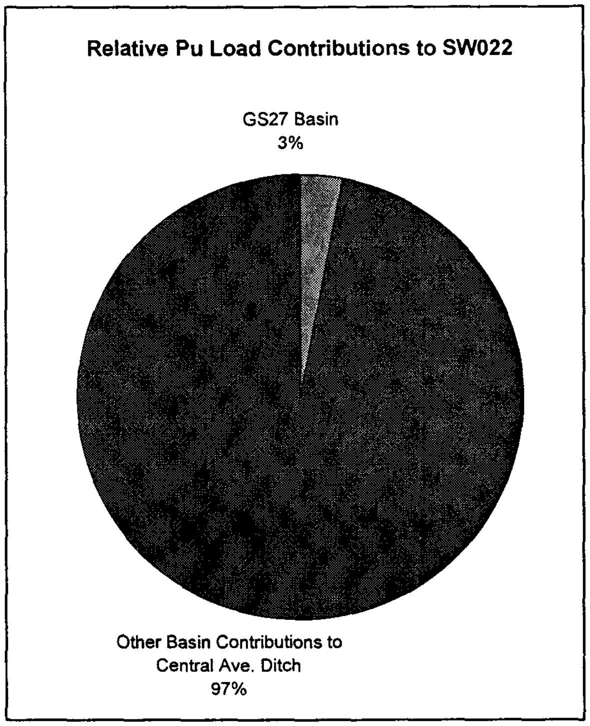

Figure 6-14. Relative Sub-Basin Loads to SW022: WY97-WY98.

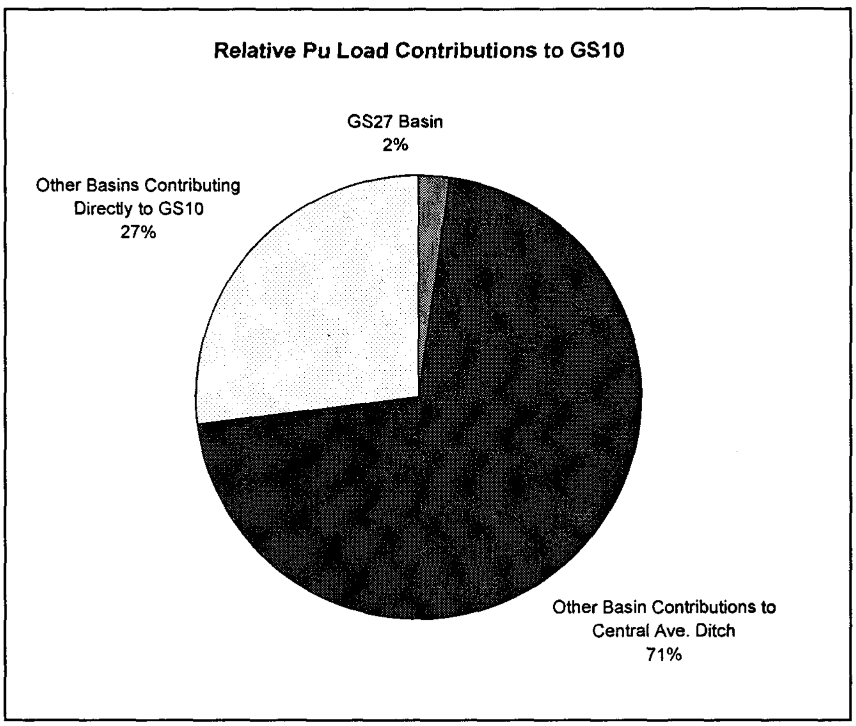

Figure 6-15. Relative Sub-Basin Loads to GS10: WY97-WY98.

6.1.3. Data Correlations

Flow Rates and TSS

As stated previously, Pu tends to form strong associations with particulate matter (as shown in Figure 6-16 for GS10). If these particles are transported in surface water, then so is Pu. During high intensity precipitation events, with increased raindrop impact, higher quantities of solids are transported in overland flow. Similarly, higher flow rates in ditches and creeks, generally result in increased TSS values due to higher flow velocity and turbulence.

Figure 6-17 shows the variation of Pu activity with flow for GS10. The activity plotted is the analytical result for the sample; the flow is the average of the flow rates during each composite grab. An upward trend generally indicates the increased movement of Pu during higher flow rates. This can occur when the source is widespread (movement through overland flow and raindrop impact), or when the source exists in the streambed itself (movement through increased scouring). These are the mechanisms commonly seen at other Site monitoring locations, and Figure 6-17 indicates a general upward trend in activity with higher flow rates. The AMS will include an evaluation of TSS in surface water and the associated radionuclides. This analysis should provide some insight into the transport mechanisms of Pu which is associated with particulate matter.

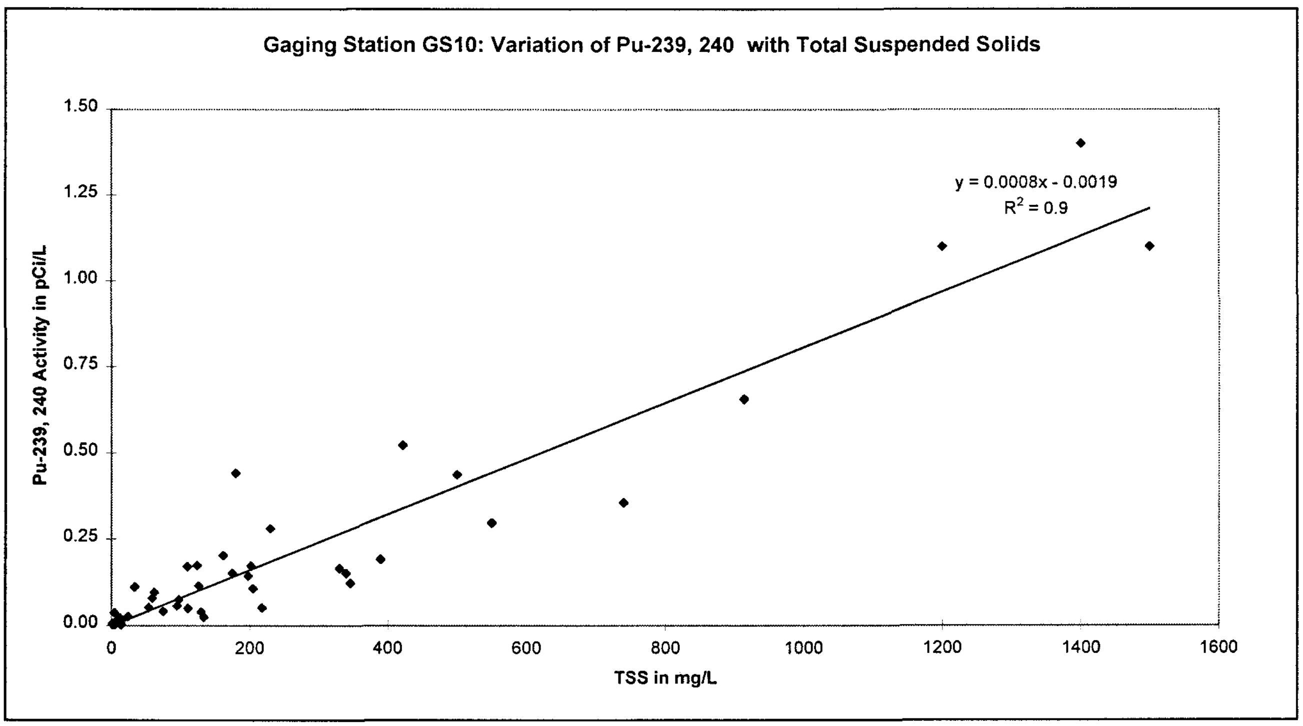

Figure 6-16. Variation of Pu with TSS at GS10.

Variation could be caused by variations in precipitation, some physiochemical or biological phenomena, some 'hot particle' mechanism, radiochemical analyses by different subcontractor laboratories, or a

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changing drainage basin. For example, similar precipitation events with similar runoff rates could give different activities if the precipitation was more intense on a localized source area. Precipitation runoff transporting soils from relatively contaminated areas could result in higher Pu to flow ratios, and vice versa. Regardless, it is apparent that transport of actinides in the environment and the associated variability is not fully understood.

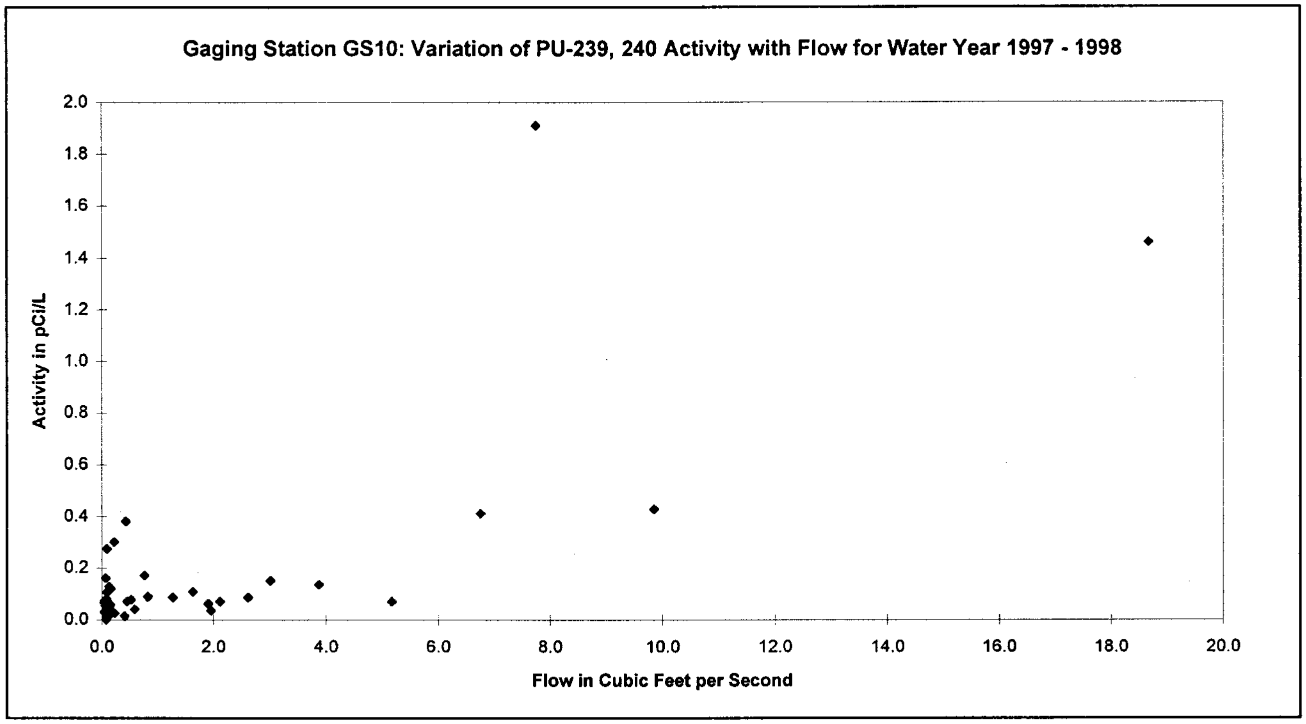

Figure 6-17. Variation of Pu Activity with Flow Rate at GS10: WY97-WY98.

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7. GS10 SOURCE EVALUATION

In the following section, a discussion of source hypotheses for GS10 is presented. To date, a singular source for GS10 can not be identified. Information collected to date does not point to any singular conclusion. In fact, it is likely that multiple sources and transport mechanisms are responsible for the elevated activities at GS10. *To date, no localized areas of radiological contamination have been identified — either historical or resulting from current operations. The Site concludes that the likely source of the exceedance of the 30-day average for Pu and Am at POE GS10, resulted from diffuse radionuclide contamination from past Site operations released to the environment through events and conditions over past years.*

7.1. WIDESPREAD OR LOCALIZED SOIL AND SEDIMENT CONTAMINATION IN GS10 DRAINAGE

Site soils have received contamination from various historical releases. Section 4.7 in Progress Report #2 identifies numerous events from the Site's production era which introduced radioisotopes to Site drainages via both airborne and surface-water runoff pathways. As discussed in Section 4 of Progress Report #2, historical reports and a recent review of existing soil/sediment data indicate widespread Pu contamination of soils and sediments throughout the GS10 drainage. The GS10 drainage includes numerous IHSSs and Pu source areas. The movement of contaminated soils and sediments in runoff could result in localized contaminated deposits or more evenly distributed contamination, depending on natural erosion processes in the GS10 drainage. Airborne contamination has resulted in more distributed contamination, with levels diminishing further from sources such as the 903 Pad (Liator, 1995).

Soil and sediment activities for samples in the GS10 drainage show a range of 0 to more than 4,000 pCi/g (see Section 4.6 of Progress Report #2). The highest values are associated with soils under the 903 Pad, and therefore do not come in contact with runoff. Most of the results are in the 0.1 to 10 pCi/g range. If it is assumed that Pu is associated with soil solids measurable as TSS, and that TSS represents a uniform suspension of all soil fractions (i.e. TSS maintains the same particle size and composition ratios as the surface soils), surface water activity could be calculated directly from soil activity for a given TSS concentration. Table 7-1 presents the results of such calculations. Specifically, Table 7-1 shows the calculated surface water sample activities at GS10 which would result from a given basin soil activity, assuming uniform suspension of surface soils as TSS and complete association of Pu with TSS in solution. The ranges of TSS concentrations and basin soil activities used in the calculations are based on actual, observed values from the GS10 basin.

Based on calculations summarized in Table 7-1, the elevated activities observed at GS10 are possible. Section 4.2 of Progress Report #2 and Section 6.1.2 of this Report show that the currently monitored GS10 sub-basins all contribute Pu load to GS10, further supporting the hypothesis of multiple or widespread source areas. Additionally, the apparent relationship between TSS, precipitation, and Pu activity supports this hypothesis. It is also possible that soils are eroded, moved by overland flow, and re-deposited in ditches with each passing storm runoff event. Further, it is possible that 'hot particles' or preferential suspension of

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Pu-associated solids is occurring in the drainage. Sections 5.1 and 5.3 provide further insight into the transport and speciation issues influencing surface-water activities. AMS work evaluating soil/sediment and surface-water TSS speciation, and the associated radionuclide activities will provide additional understanding of transport mechanisms of Pu in surface water.

Table 7-1. Calculated Surface Water Activities Assuming Uniform Soil Suspension and Complete Association of Pu with Suspended Solids for GS10.

	Total Suspended Solids (TSS)	
Basin Soil Activity Ranges (pCi/g)	**250 mg/l (Average)**	**1,500 mg/l (Maximum)**
0.1	0.025 pCi/l Pu	0.15 pCi/l Pu
1 to 10	0.25 to 2.5 pCi/l Pu	1.5 to 15 pCi/l Pu
100	25 pCi/l Pu	150 pCi/l Pu

Data collected from Performance monitoring location GS37 and Source Location monitoring locations GS38, GS39, and GS40 will further determine the proportions of Pu load that each monitored sub-basin may be contributing. If a certain sub-basin is determined to be contributing a significant proportion of the load at GS10, that basin could be further characterized through soil/sediment sampling, and watershed improvements may be used to mitigate further transport. These types of watershed improvements have been demonstrated for other locations around the Site, specifically GS27 (see Sections 4.2 and 4.3 of Progress Report #2).

7.2. LOCALIZED CONTAMINATION NEAR GS10 SAMPLING LOCATION

The Historical Release Report (U.S. Department of Energy, 1992) supports the hypothesis that localized contamination exists in the drainage immediately upstream of GS10, specifically the sediments in the stream reach between B991 and GS10. The area was identified in the Historical Release Report due to past radioactive releases to the B-series drainages (as discussed in Section 4.7 of Progress Report #2), and the soil in the area is potentially contaminated with radionuclides.

As stated in the previous section, data collected from Performance monitoring location GS37 and Source Location monitoring locations GS38, GS39, and GS40 will further determine the proportions of Pu load that each monitored sub-basin may be contributing. If the sub-basins upstream from these areas (around B991 and 995) are shown to be contributing a small proportion of the load at GS10, then this area may be contributing a significant proportion of the load. Sediment samples could then be collected to evaluate the sediments in this stream reach.

7.3. TRIBUTARY SURFACE-WATER SOURCE

Another hypothesis to address is that radionuclide contamination of surface water observed at GS10 originated from surface water tributary to GS10. Section 4.2 of Progress Report #2 shows that the GS10 sub-basins which are currently monitored all contribute Pu load to GS10, supporting the hypothesis that tributary surface water is carrying load toward GS10. As stated in the previous section, data collected from Performance monitoring location GS37 and Source Location monitoring locations GS38, GS39, and GS40 will further determine the proportions of Pu load that each monitored sub-basin may be contributing. To date, very few analytical results have been received from the labs for these locations (see Table 6-1). Water-quality data from these locations will be very valuable should another exceedance occur at GS10.

If a certain sub-basin is determined to be contributing a significant proportion of the load at GS10, that basin could be further characterized through soil/sediment sampling, and watershed improvements can be used to mitigate further transport in surface water. These types of watershed improvements have been demonstrated for other locations around the Site, specifically at GS27 (see Section 4.2 of Progress Report #2). A more thorough analysis of watershed improvements is included in Section 9.4 of Progress Report #3.

8. DATA SUMMARY AND ANALYSIS FOR SW093

Progress Report #3 primarily included analysis and interpretation of environmental information for the SW093 drainage. New information collected since Progress Report #3 is included in the following section. A cross-referenced discussion of this information and the specific source location hypotheses they support (or not) are included in Section 9.

8.1. AUTOMATED SURFACE-WATER MONITORING DATA

This section presents data summary and analysis for environmental information collected at gaging stations SW093 (N. Walnut Creek above Pond A-1) and upstream tributary locations SW118 (N. Walnut Creek above Portal 3), and GS32 (pipe draining B779 basin) as shown in Figure 8-1.[25] Data presented include flow rates, discharge volumes, radionuclide activities, radionuclide loads, and water-quality parameters. Analysis was performed on averages of all data available from WY93 to present, the continuous flow-paced samples from WY97, and the periods of WY98 that are available[26,15]. Only Pu was elevated at SW093, and this section focuses on the transport and source location for Pu only.

8.1.1. Data Summary

Significant data exists for flow and radionuclide activities at SW093. Information for TSS, metals, major ions, etc. is limited. Additional information for these parameters may need to be collected if the progress of the ongoing source evaluation demonstrates the need for additional data to draw definite conclusions. Individual results are averages of target, duplicate, and replicate results for each sample. Results which were rejected through the validation process are not included. All activities are for total radionuclides and negative results are set to zero for calculation purposes.

Reliable flow record has been collected at SW118 since February 1996. Water-quality information at SW118 is very limited to date. SW118 has recently been upgraded with sampling equipment to become a Source Location monitoring station in support of the source evaluation for SW093. SW118 collects continuous flow-paced samples for Pu, Am, and TSS. This water-quality information will be used to calculate load contributions to SW093 as part of the increased scope for the ongoing RFCA monitoring.

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[25] SW118 was upgraded to a Source Location station in response to the exceedances measured at SW093 as part of the source evaluation.

[26] Flow data is included for the period 10/1/92 - 2/28/98; analytical data is included for the period from 10/1/92 - 2/28/98, where available from the labs.

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GS32 collects storm-event samples for TSS, Pu, Am, U, and metals as a Performance monitoring location in support of the D&D of B779. GS32 has been collecting samples since April 1997, and four samples have been analyzed to date. Flow can not be effectively measured at this location[27], consequently, samples are time-paced. Discharge volumes will need to be estimated based on the relative drainage basin area. Load contributions to SW093 will be calculated when more analytical results are available as part of the increased scope for the ongoing RFCA monitoring. Future information collected at the other proposed Source Location stations tributary to SW093, should they be installed (see Section 11.2.1), will also be used for load calculations.

Surface-Water Flow Rates and Discharge Volumes

A reliable flow record has been collected at SW093 since WY93, and since February 1996 at SW118. Flow data included in this Final Report for these locations ends on February 28, 1998. Relative average annual discharge percent to SW093 from SW118 is 24%. Variation of flow rates and discharge volumes is significant at SW093, and coincides with variation in precipitation (as shown on Figure 8-2 and Figure 8-3). Baseflow at SW093 is nearly continuous year-round.

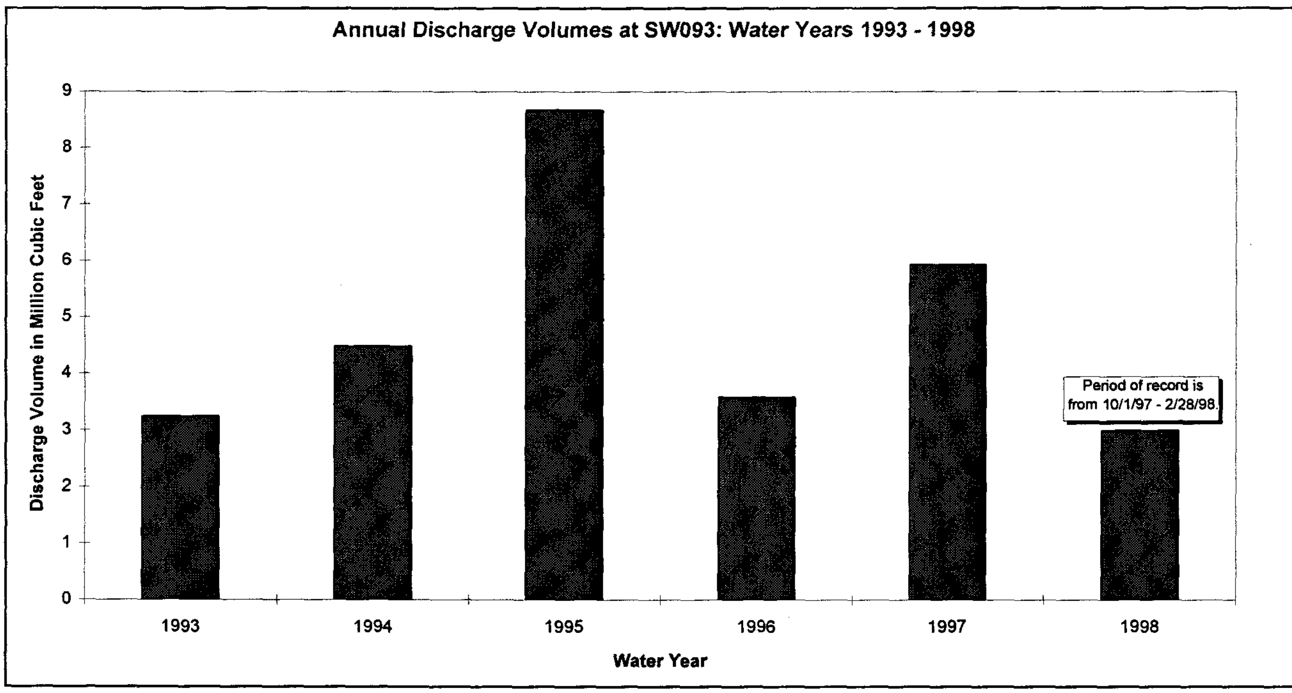

Figure 8-2. Annual Discharge Volumes for SW093.

[27] GS32 samples water discharging from a corrugated metal pipe (cmp) draining the B779 area. The cmp discharges at a very steep grade. Therefore, a simple Manning's calculation can not be use to measure flow from a measured water level. Significant modification of the cmp or the installation of a secondary flow control structure would be required to measure flow accurately.

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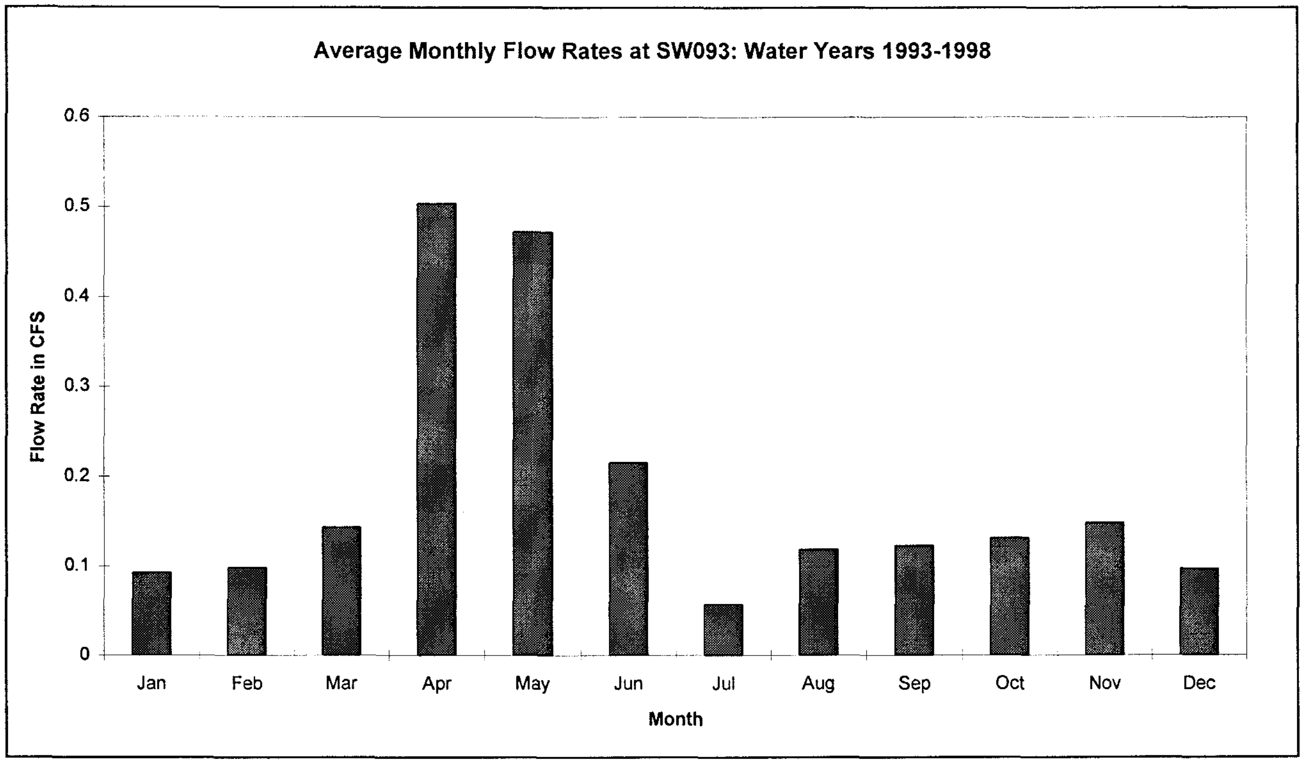

Figure 8-3. Average Monthly Flow Rates at SW093.

Radionuclide Activities

Individual analytical results for Pu at SW093 and GS32 are shown in Figure 8-4 and Figure 8-5, respectively. All sample results are plotted regardless of sampling protocol employed[28]. The large variation in activities is evident in these plots. This variation could be caused by variations in precipitation, some physiochemical or biological phenomena, some 'hot particle' mechanism, or a changing drainage basin. For example, similar precipitation events with similar runoff rates could give different activities if the precipitation was more intense on a localized source area. Regardless, it is apparent that transport of actinides in the environment and the associated variability is not fully understood. Summary statistics for gaging stations SW093, SW118, and GS32 are shown in Table 8-1. These activities are arithmetic averages, which do not take into account the hydrologic conditions during sampling (storm-event, baseflow, etc.), the flow rate (more importantly, the discharge volume), or the sampling protocol. The recent elevated results at

[28] Individual grabs, time-paced (scheduled grabs) composites, storm-event (hydrograph rising limb) flow-paced composites, and continuous flow-paced composites are shown. For a discussion of sample collection methods, see Section 6.2.4 in Progress Report #1.

SW093 (Figure 8-4) are from samples collected during large precipitation events during the period August 1 through August 4, 1997.

Table 8-1. Summary Statistics for Samples from Gaging Stations in SW093 Drainage.

Sampling Location	Number of Samples	Average[a] Activity (pCi/l)	Maximum Result (pCi/l)	Standard Deviation[b] (pCi/l)
SW093				
WY93 - WY98	67	0.251	5.3	0.834
SW118				
WY98	2	0.004	0.008	0.006
GS32				
WY97 - WY98	6	0.707	2.55	0.962

[a] Arithmetic average
[b] Assumes normal distribution for simplicity.

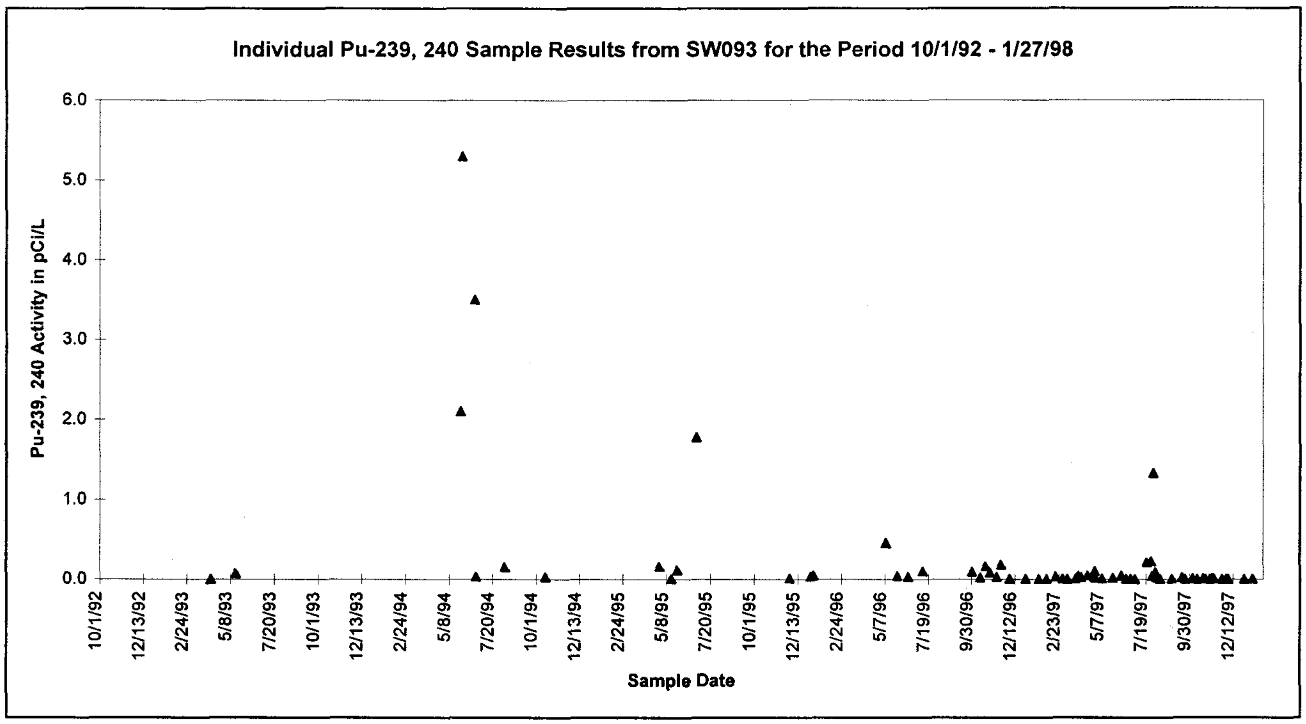

Figure 8-4. Individual Analytical Pu Results for SW093.

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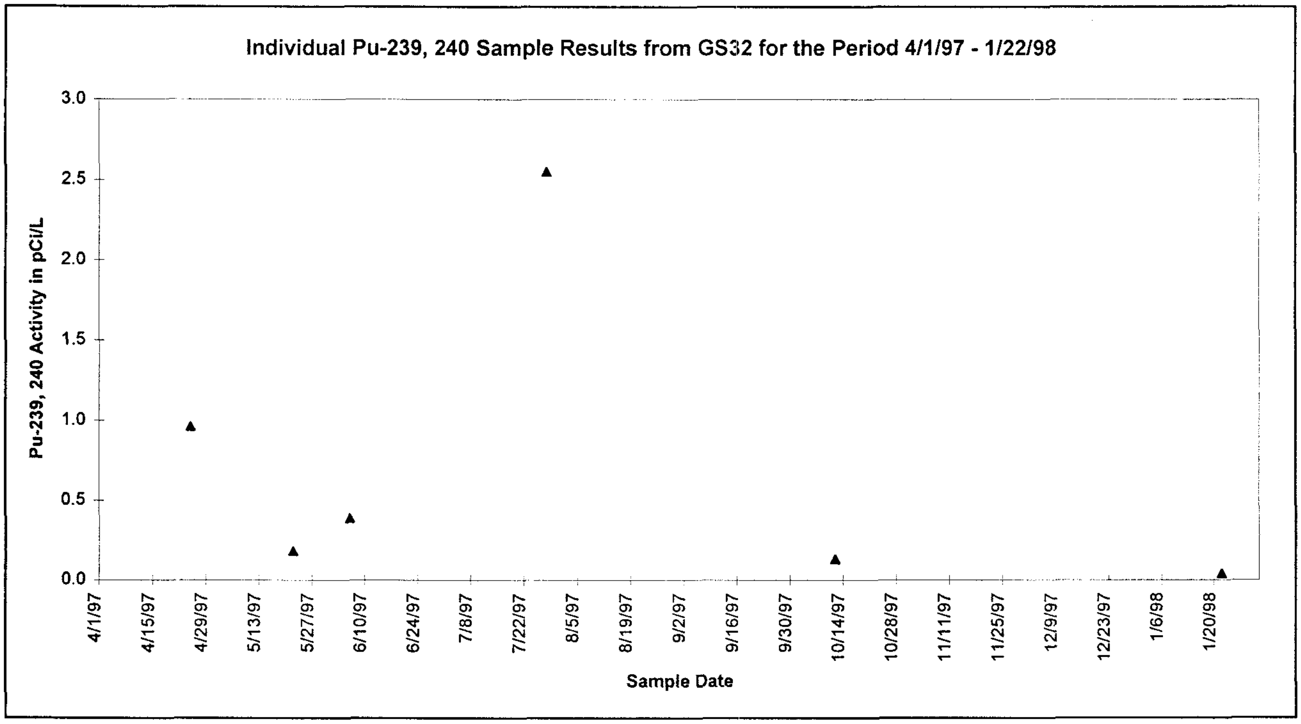


Figure 8-5. Individual Analytical Pu Results for GS32.

Figure 8-6 shows the average annual activities at SW093 for WY93 - WY97. For WY93 - WY96, arithmetic averages are plotted. However, due to the continuous flow-paced sampling protocols currently in place, the more representative volume-weighted average activity is shown for WY97. This volume-weighted average is calculated in a fashion similar to 30-day averages[5], except that the period is for an entire water year.[29] It is important to note that although elevated measurements were made in WY97, the volume-weighted average is small compared to the arithmetic average activities for other years. Figure 8-7 shows monthly arithmetic average activities which increase for months with higher rainfall and flow rates which are shown on Figure 8-3.

[29] Each carboy has a load in pCi calculated from the activity and the associated creek discharge volume. The total load in pCi for all samples is then divided by the total creek discharge volume to give the volume-weighted activity in pCi/l.

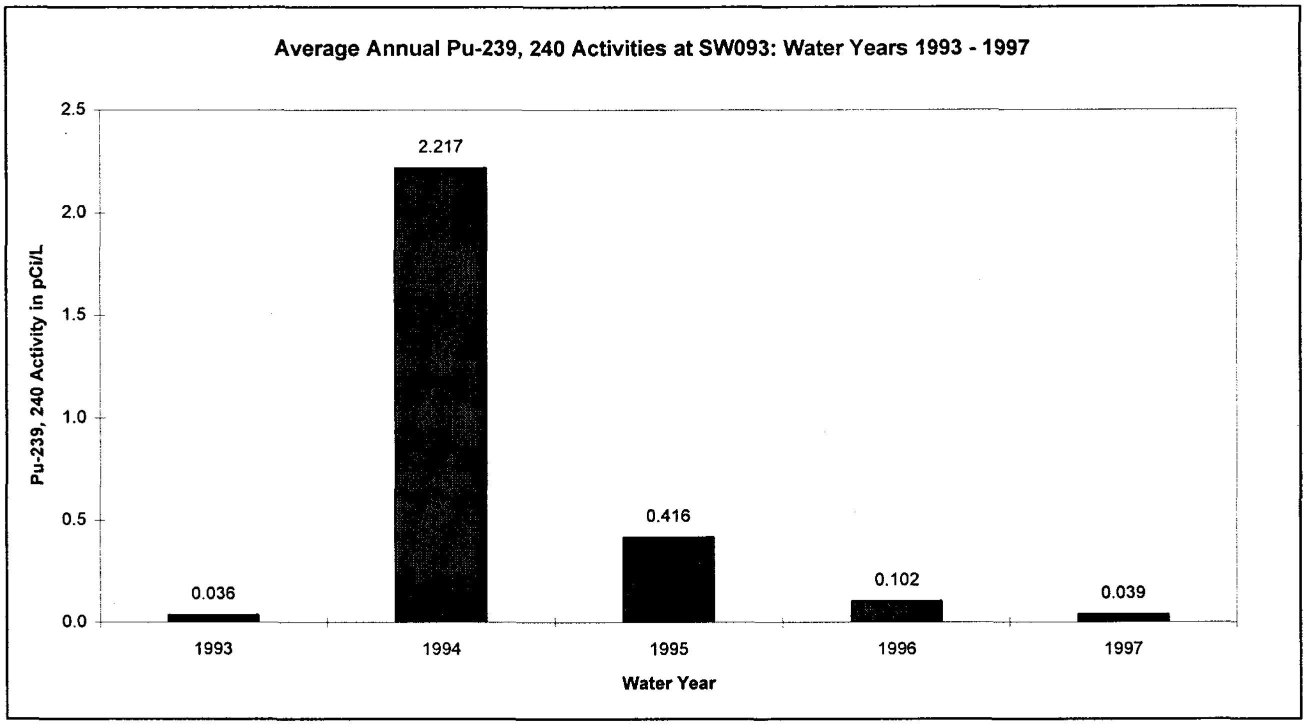
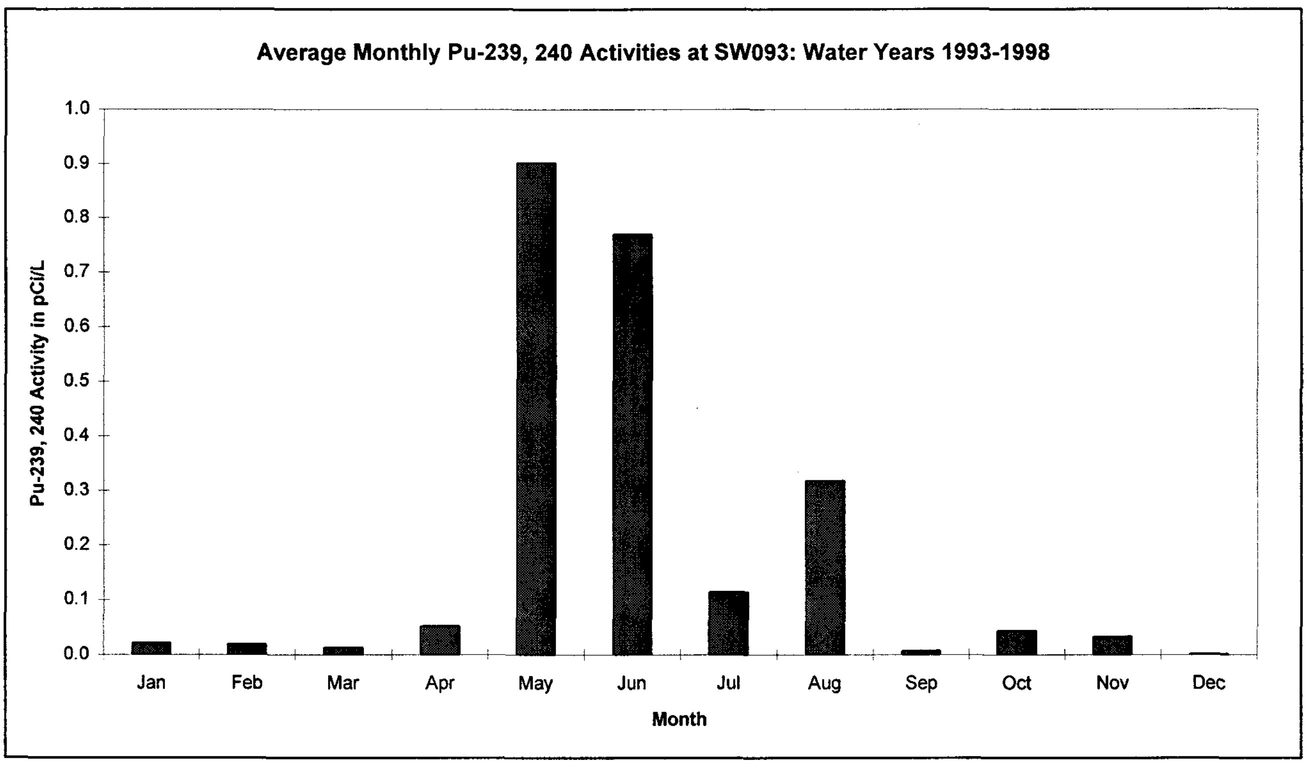


Figure 8-6. Average Annual Pu Activities for SW093.



All averages are arithmetic.

Figure 8-7. Average Monthly Pu Activities at SW093.

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8.1.2. Loading Analysis

This loading analysis will only include gaging station SW093. Performance monitoring location GS32 and Source Location monitoring station SW118 will not be included at this time due to the limited number of samples collected to date (see Table 8-1). These locations will be included in future loading calculations as part of the increased monitoring scope the Site has undertaken. Incorporation of loading data from these stations will help to quantify loads from the corresponding subbasins contributing to SW093. These calculations will define the loads from each subbasin to indicate general location of discrete sources or to support the hypothesis of a distributed diffuse source.

WY93 - WY98 Monitoring Data

Annual loads for SW093 in micrograms are plotted in Figure 8-8. For WY93 - WY96, the arithmetic average activity is multiplied by the associated total annual discharge volume, then converted to micrograms. For WY97, the activity for each flow-paced composite is multiplied by the associated discharge volume, then converted to micrograms and totaled.

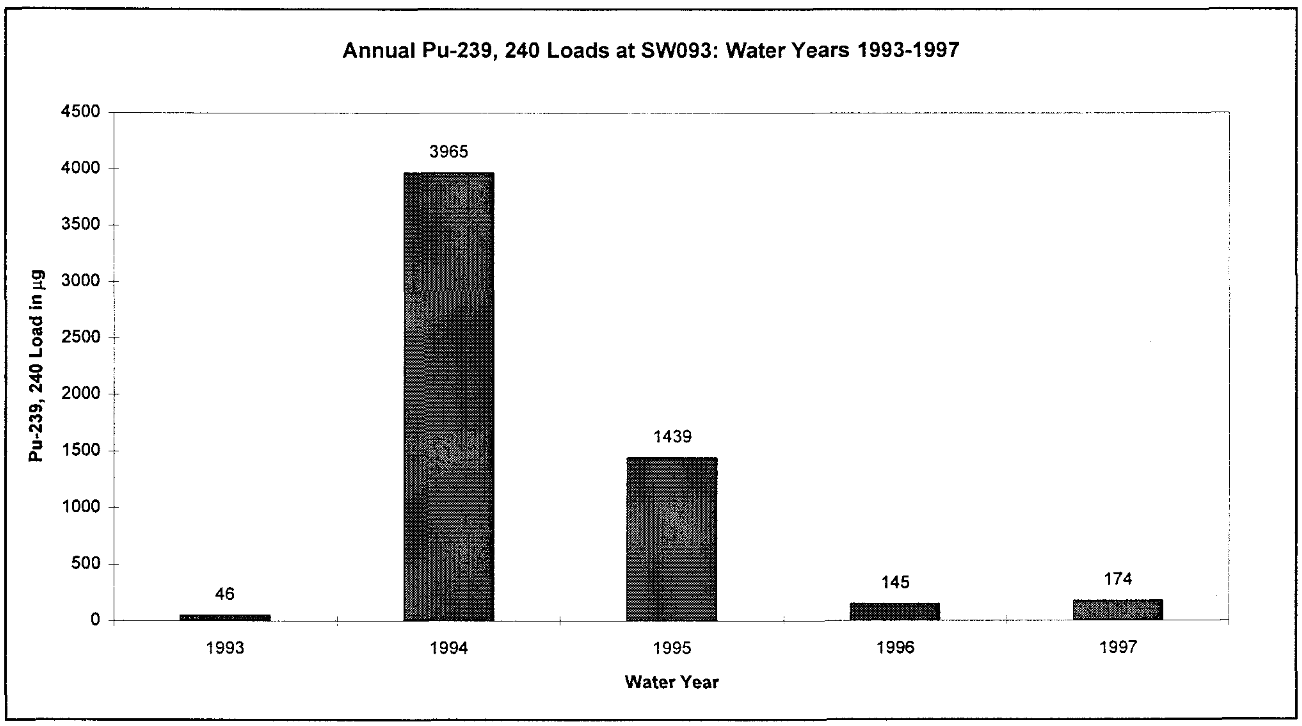

Figure 8-8. Annual Pu Loads at SW093.

WY97 and WY98 Continuous Flow-Paced Monitoring Data

Figure 8-9 shows volume-weighted average monthly activities for continuous flow-paced samples collected in WY97 an WY98 at SW093. Analytical results are available through January 27, 1998.

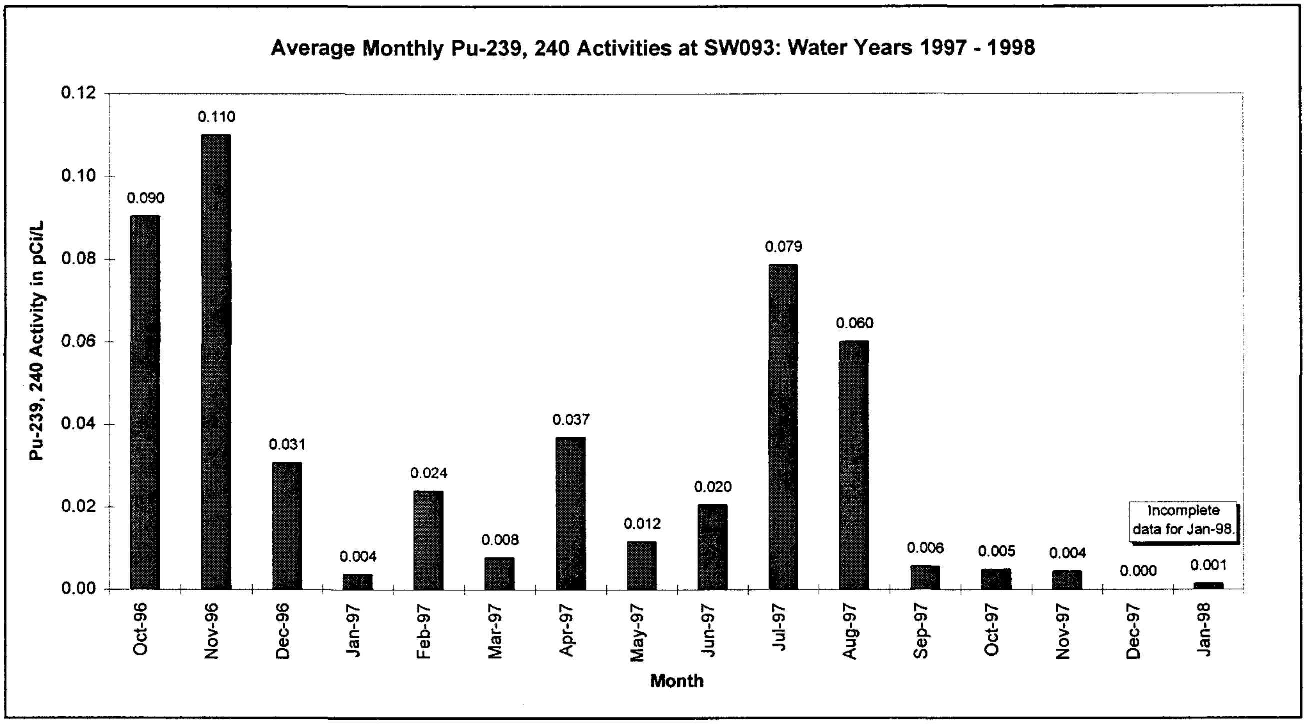

Figure 8-9. Average Monthly Pu Activities for WY97 at SW093.

Detail for each continuous flow-paced composite sample for WY97 at SW093 is presented in Table A-12. Elevated samples are indicated in bold. It is important to note the variable activity for the samples. It is apparent that the variability of surface-water activity and the transport mechanisms for Pu are not fully understood. Variations in intensity of precipitation events, with increased raindrop impact, could result in varying quantities of solids transported in overland flow. Similarly, variable flow rates in ditches and creeks generally result in variable TSS values due to varying flow velocities and turbulence. Additionally, seasonal changes in biological and chemical processes may influence Pu transport.

Prior to WY97, SW093 collected flow-paced storm-event samples. During WY97, continuous flow-paced sampling protocols were implemented. When comparing the SW093 protocols, the WY97 volume-weighted average is 0.039 pCi/l Pu, while the WY93-WY96 arithmetic average of storm-event samples was 0.734 pCi/l Pu. It is not clear if this change in activity can be attributed to overall improvement in water-quality and/or the change in sampling protocols at SW093. For a discussion of the sampling protocol changes see Section 6.2.4 in Progress Report #1.

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8.1.3. Data Correlations

Flow Rates and TSS

As stated in previously, Pu tends to form strong associations with particulate matter (as shown in Figure 6-16 for GS10). If these particles are transported in surface water, then so is Pu. During high intensity precipitation events, with increased raindrop impact, higher quantities of solids are transported in overland flow. Similarly, higher flow rates in ditches and creeks, generally result in increased TSS values due to higher flow velocity and turbulence. Figure 8-10 indicates an upward trend, but not a strong correlation, in Pu activity with increasing TSS. Variation may be attributed to variable precipitation within the drainage which could fall on areas of differing contamination levels, or preferential association of Pu with specific particulate fractions based on physiochemical mechanisms. Precipitation runoff transporting soils from relatively contaminated areas could result in higher Pu to TSS ratios, and vice versa.

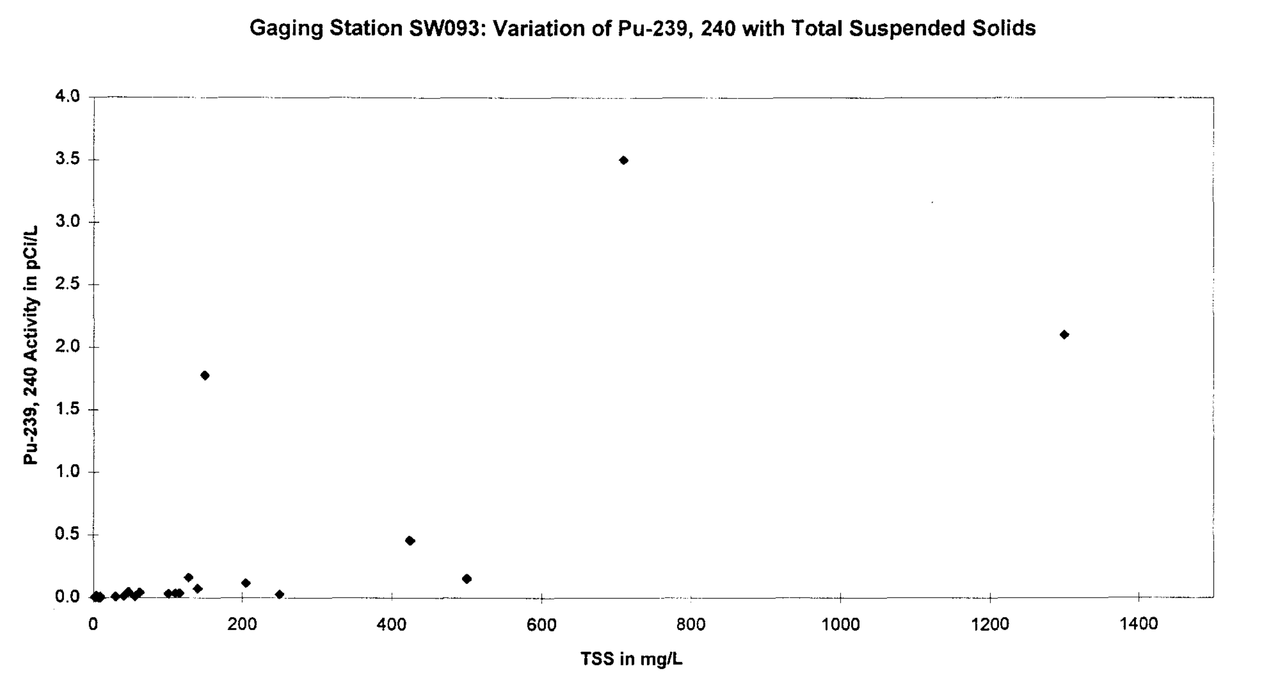

Figure 8-10. Variation of Pu with TSS at SW093.

Figure 8-11 show the variation of Pu activity with flow for SW093. The activity plotted is the analytical result for the sample; the flow is the average of the flow rates during each composite grab. An upward trend generally indicates the increased movement of Pu during higher flow rates. This can occur when the source is widespread (movement through overland flow and raindrop impact), or when the source exists in the streambed itself (movement through increased scouring). These are the mechanisms commonly seen at other Site monitoring locations, and Figure 8-11 indicates a general upward trend in activity with higher flow rates. The AMS will include an evaluation of suspended solids in surface water and the associated

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radionuclides. This analysis should provide some insight into the transport mechanisms of Pu which is associated with particulate matter.

Variation could be caused by variations in precipitation, some physiochemical or biological phenomena, some 'hot particle' mechanism, radiochemical analyses by different subcontractor laboratories, or a changing drainage basin. For example, similar precipitation events with similar runoff rates could give different activities if the precipitation was more intense on a localized source area. Precipitation runoff transporting soils from relatively contaminated areas could result in higher Pu to flow ratios, and vice versa. Regardless, it is apparent that transport of actinides in the environment and the associated variability is not fully understood.

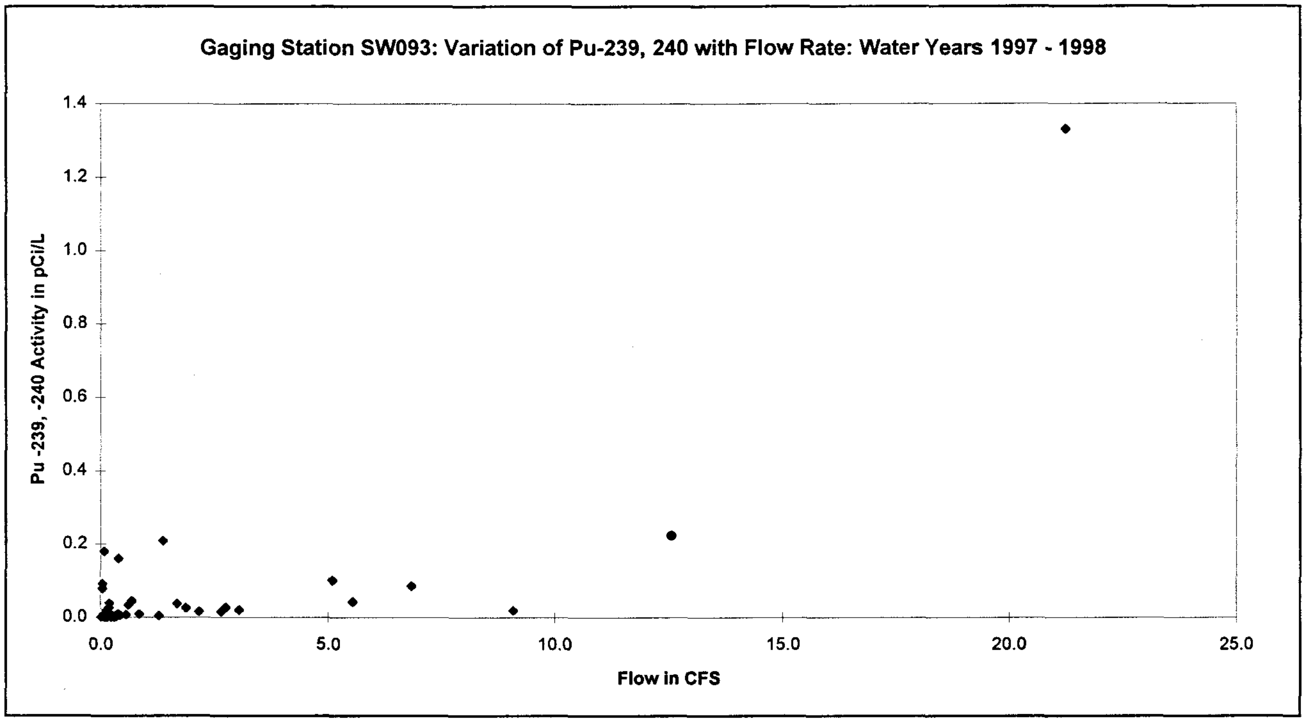

Figure 8-11. Variation of Pu Activity with Flow Rate at SW093: WY93 - WY98.

9. SW093 SOURCE EVALUATION

In the following section, a discussion of source hypotheses for SW093 is presented. To date, a singular source for SW093 can not be identified. Information collected to date does not point to any singular conclusion. In fact, it is likely that multiple sources and transport mechanisms are responsible for the elevated activities at SW093. *To date, no localized areas of radiological contamination have been identified — either historical or resulting from current operations. The Site concludes that the likely source of the exceedance of the 30-day average for Pu at POE SW093, resulted from diffuse radionuclide contamination from past Site operations released to the environment through events and conditions over past years.*

9.1. WIDESPREAD OR LOCALIZED SOIL AND SEDIMENT CONTAMINATION IN SW093 DRAINAGE

Site soils have received contamination from various historical releases. Section 7.6 in Progress Report #3 identifies numerous events from the Site's production era which introduced radioisotopes to Site drainages via both airborne and surface-water runoff pathways. As discussed in Section 8, historical reports and a recent review of existing soil/sediment data indicate widespread Pu contamination of soils and sediments throughout the SW093 drainage. The SW093 drainage includes numerous IHSSs and Pu source areas. The movement of contaminated soils and sediments in runoff could result in localized contaminated deposits or more evenly distributed contamination, depending on natural erosion processes in the SW093 drainage. Airborne contamination has resulted in more distributed contamination, with levels diminishing with distance from localized sources.

Soil and sediment activities for samples in the SW093 drainage show a range of 0 to more than 100 pCi/g (see Section 7.5 of Progress Report #3). The highest values are associated with soils near B779. Most of the results are in the 0.01 to 1 pCi/g range. If it is assumed that Pu is associated with soil solids measurable as TSS, and that TSS represents a uniform suspension of all soil fractions (i.e. TSS maintains the same particle size and composition ratios as the surface soils), surface water activity could be calculated directly from soil activity for a given TSS concentration. Table 9-1 presents the results of such calculations. Specifically, Table 9-1 shows the calculated surface water sample activities at SW093 which would result from a given basin soil activity, assuming uniform suspension of surface soils as TSS and complete association of Pu with TSS in solution. The ranges of TSS concentrations and basin soil activities used in the calculations are based on actual, observed values from the SW093 basin.

Based on calculations summarized in Table 9-1, the elevated activities observed at SW093 are possible. Section 7.5 of Progress Report #3 indicates that the SW093 sub-basins may all contribute Pu load to SW093 at varying levels, further supporting the hypothesis of multiple or widespread source areas. It is also possible that soils are eroded, moved by overland flow, and re-deposited in ditches with each passing storm runoff event. These deposited sediments could then be re-suspended by subsequent events to provide Pu activity at SW093. Further, it is possible that 'hot particles' or preferential suspension of Pu-associated

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solids is occurring in the drainage. Sections 5.1 and 5.3 provide further insight into the transport and speciation issues influencing surface-water activities. AMS work evaluating soil/sediment and surface-water TSS speciation, and the associated radionuclide activities will provide additional understanding of transport mechanisms of Pu in surface water.

Table 9-1. Calculated Surface Water Activities Assuming Uniform Soil Suspension and Complete Association of Pu with Suspended Solids for SW093.

	Total Suspended Solids (TSS)	
Basin Soil Activity Ranges (pCi/g)	**240 mg/l (Average)**	**1,900 mg/l (Maximum)**
0.01 to 1	0.0024 to 0.24 pCi/l Pu	0.019 to 1.9 pCi/l Pu
100	24 pCi/l Pu	190 pCi/l Pu

Data collected from Performance monitoring location GS32, Source Location monitoring location SW118, and future proposed Source Location monitoring locations will further determine the proportions of Pu load that each monitored sub-basin may be contributing. If a certain sub-basin is determined to be contributing a significant proportion of the load at SW093, that basin could be further characterized through soil/sediment sampling, and watershed improvements may be used to mitigate further transport. These types of watershed improvements have been demonstrated for other locations around the Site, specifically GS27 (see Sections 4.2 and 4.3 of Progress Report #2).

9.2. TRIBUTARY SURFACE-WATER SOURCE

Another hypothesis to address is that radionuclide contamination of surface water observed at SW093 originated from surface water tributary to SW093. Section 7.5 of Progress Report #3 indicates that the SW093 sub-basins may all contribute Pu load to SW093 at varying levels, supporting the hypothesis that tributary surface water is carrying load toward SW093. As stated in the previous section, data collected from Performance monitoring location GS32, Source Location monitoring location SW118, and future proposed Source Location monitoring locations will further determine the proportions of Pu load that each monitored sub-basin may be contributing. If a certain sub-basin is determined to be contributing a significant proportion of the load at SW093, that basin could be further characterized through soil/sediment sampling, and watershed improvements may be used to mitigate further transport. These types of watershed improvements have been demonstrated for other locations around the Site, specifically at GS27 (see Sections 4.2 and 4.3 of Progress Report #2).

10. MITIGATING ACTIONS

Findings of this investigation indicate that the Walnut Creek drainage basin contaminant source is diffuse - a by-product of activities occurring throughout the history of the Site. Proposed methodologies for mitigating the contaminant source are based on these findings and the subsequent assumption that a radiological "hot spot" is not the cause of elevated plutonium activity observed in Walnut Creek. Options for potential mitigating actions for a diffuse plutonium source in both Walnut and Woman Creeks are summarized below (and discussed in further detail in Sections 10.1 through 10.3).

- Stabilize or "fix-in-place" above-background Pu-contaminated soils and sediments that could contribute to an exceedance;

- Remove above-background Pu-contaminated soils and sediments that could contribute to an exceedance;

- Construct a dam immediately west of Indiana Street for use as a passive settling reservoir only, or as a passive settling reservoir in conjunction with an active treatment system.

These options represent only potential solutions. Each may require further evaluation to determine if it is indeed a fully viable alternative for resolving concerns regarding elevated Pu activity in Walnut Creek. Complications associated with the implementation of mitigating alternatives include the relative project scope (reallocating significant funding resources to mitigating actions while simultaneously closing the Site) and ecological issues (Walnut Creek in this location is known Preble's Mouse habitat).

10.1. STABILIZATION OF SOILS AND SEDIMENTS

Erosion control measures were implemented at the Site during FY96 and FY97 in an effort to stabilize and entrap soils and sediments likely to be transported from watersheds by stormwater runoff. Based on recognized characteristics of radionuclides and stormwater, removing particulate matter to which radionuclides sorb should reduce radionuclide loading to the water (References - see Progress Report #3, pg. 73, Refs. 17 - 22). These control measures, including an acrylic co-polymer soil sealant and a wood fiber-based soil stabilizer/revegetation product, were discussed in Progress Report #3, Section 9.

Experience has shown that the improvements improve water quality most measurably when applied to the majority of a basin that has large areas of exposed dirt, susceptible to erosion, with above-background levels of radionuclide activity in the soil. This was the case with the GS27 drainage basin, located in the Industrial Area adjacent to the former site of B889 (Reference - Progress Report #3, Section 9.4). Improvements in water quality are less measurable when areas susceptible to erosion are not obvious prior to the improvements being implemented.

Within the Industrial Area, extensive areas of bare soil exist where erosion control measures would be appropriate. However, downstream from the detention ponds, in the area where much of the investigative effort was directed, the majority of the drainage basin is vegetated and not prone to erosion. Locations where the soil stabilizers would be applied are not obvious, and resulting positive impacts on Walnut Creek water quality are unknown.

10.2. REMOVAL OF SOILS AND SEDIMENTS

As discussed previously, no radioactively contaminated soil or sediment "hotspots" have been detected to date that appear related to elevated Pu activity observed in Walnut Creek surface water. This assessment includes a preliminary review of the data just received following extensive soil sampling in the Walnut Creek basin in February 1998 (see Section 4.2). If the new soils data had revealed the presence of notably elevated Pu activity in soil at a specific location within the Walnut Creek basin, then removal of those soils could have been warranted and relatively practicable.

In contrast, if further analysis of the new soils data were to indicate that widespread (versus localized) areas of soil have levels of Pu that are sufficient enough to cause adverse water quality impacts, then several issues would have to be addressed. The benefits to water quality of removing the expanse of contaminated soils would have to be weighed against the complications associated with excavating such a large area, including controlling off-Site airborne releases during the excavation, stabilizing the watershed following the soil removal to prevent further degradation of water quality, wildlife habitat impacts, and managing the volumes of waste generated from such a project.

Soils and sediment data do not indicate an apparent source area where soil or sediment removal is the obvious solution. Further assessment of this remediation option is dependent on completion of laboratory quality assurance protocols and performance of a more rigorous analysis of the recently received soil sampling data.

10.3. CONSTRUCTION OF NEW RESERVOIRS

The efficiency in removing Pu from the water column through use of the Site detention ponds is well documented (Reference to Section 6, Progress Report #2). Surface water monitoring data indicate that influent to the ponds has roughly ten times the Pu activity of water flowing out of the ponds. This indicates the effectiveness of settling as a mechanism for removal of Pu from the water column. This improvement in water-quality between pond influent (runoff from the Industrial Area to the Ponds) and effluent (water discharged from the terminal ponds) confirms that the Site's water-management practices help to reduce migration of contamination.

Construction of a new detention pond immediately west of Indiana Street therefore represents another option for mitigating Pu activity in Walnut Creek. This pond would not only detain discharges from the A- and B-Series ponds, but would also capture runoff from the basin downstream from the existing ponds and flows from No Name Gulch. In order to effectively improve water quality at the RFETS fenceline year around, the pond would have to be sized to detain water from large storm events, when plutonium tends most to be mobilized and transported in surface water.

Major complications associated with the new pond alternative include the relative project scope (reallocating significant funding resources to construct a new dam while simultaneously closing the Site) and ecological issues (Walnut Creek in this location is known Preble's Mouse habitat).

An additional option for the new detention pond alternative would be an active treatment system. Influent into the new pond would be attenuated and held, benefiting from settling time, prior to treatment and off-Site discharge. Many components of such a treatment system, for the large water volumes and low plutonium activity treatment levels being discussed, are not proven. In addition, such a process would very likely generate large volumes of low-level waste.

11. PROGRAM STATUS, ISSUES, AND HIGHLIGHTS

11.1. SAMPLING AND ANALYSIS

11.1.1. Verification of Elevated Analytical Results

Since Progress Report #1 all results returned to date from the analytical labs have met the required Quality Assurance/Quality Control criteria and no re-runs have been required. All data that contributed to the exceedance at GS03 were validated under criteria established by the Site and found to be valid. The Site continues to aggressively manage laboratory data quality and performance to assure timely delivery and reporting of accurate water-quality information.

11.2. AUTOMATED SURFACE-WATER MONITORING

11.2.1. Continuous Flow-Paced Sampling

As discussed previously, no localized sources have been identified to date as the origin of the elevated activities observed at GS03, GS10, and SW093. Consequently, continued operation of the expanded monitoring program will be the focus of efforts as opposed to remediation activities. Water quality data collected from source location monitoring stations should increase the resolution of contaminant transport from subdrainages. Data collected should also increase understanding of the seasonality and event-related variability of loading. Further, should another exceedance occur, monitoring equipment will be in place and operating to help answer important questions about the origin of the contamination and expedite source location efforts.

As part of the Walnut Creek source evaluation, seven new sampling locations have been installed, making a total of sixteen operational RFCA surface water monitoring locations within the Walnut Creek drainage on Site. Subdrainage location and sample collection status for each of the seven source locations monitoring stations is summarized in Table 11-1.

Each of these source location monitoring stations is operated to collect continuous, flow-paced samples to facilitate comparative analysis of loading. Laboratories are instructed to analyze samples for Pu and Am as well as TSS when sample collection duration does not exceed the limiting hold time of seven days. All source location samplers are paced to collect twelve samples per year. Power at each location is solar with battery backup.

These seven stations represent a 31% increase in predicted annual RFCA sample collection, raising the number of continuous, flow-paced samplers routinely operated from eight to fifteen. Addition of these sampling locations to the already intense and well targeted surface water monitoring network at the Site will help to more thoroughly delineate Site surface water. Combined with efforts from the AMS, results from

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this monitoring network may lead to predictive capabilities for and subsequently means to control transport of radionuclides in surface water.

Table 11-1 Source Location Monitoring Stations in the Walnut Creek Drainage.

Gaging Station	Installation Date	Location Description	Samples Collected
GS33	9/10/97	No Name Gulch at confluence with Walnut Creek: GS03 drainage	10/28-10/29; 10/29-11/10; 11/10-11/13; 11/13-2/19; 2/19-3/8; 3/8-3/23; 3/23-3/25; 3/25-
GS34	2/3/98	Walnut Creek at confluence with McKay Ditch: GS03 drainage	2/4-2/23; 2/23-3/23; 3/23/-4/1; 4/1-
GS35	9/12/97	McKay Ditch at confluence with Walnut Creek: GS03 drainage	10/27-10/29; 10/29-10/30; 10/30-3/25; 3/25-
GS38	1/16/98	Central Avenue Ditch northwest of Building 889 (monitors runoff downstream of the 100, 400, and 600 Areas, but be upstream of the 800 Area): GS10 drainage	2/16-3/18; 3/18-3/19; 3/19-4/2; 4/2-
GS39	1/15/98	Ditch NW of 904 Pad (monitors runoff from the areas around the 903 Pad, 904 Pad, and a portion of the Contractor Yard): GS10 drainage	1/15-1/22; 1/22-3/18; 3/18-3/19; 3/19-
GS40	3/3/98	Concrete drainage slab east of Tenth Street, south of Building 997 (monitors runoff from the areas around B776, 777, 778, 707, and 750): GS10 drainage	3/3-3/23; 3/23-
SW118	11/30/98	North Walnut Creek west of Portal 3 (monitors runoff from areas north of the PA and portions of the 300 Area): SW093 drainage	11/30-12/30; 12/30-1/19; 1/19-2/24; 2/24-3/19; 3/19-4/1; 4/1-

As part of the continuing source evaluation efforts, three more gaging stations may be installed in the SW093 drainage. First, a new station is planned for the ditch north of the Solar Ponds along the PA Perimeter Road, just west of GS32. This location will monitor runoff from the areas around B774, 771, 371, 374, 776, and 777. Second, a new station is planned for the gully east of B374 and upstream from the Metrology Lab. This location will monitor runoff from the areas around B559, 776, 566, 371, and 374. Third, a new station is planned for the small ditch west of Tank 231B. This location will monitor runoff from portions of the 100, 300, and 500 Areas.

11.2.2. POC Gaging Station Upgrades

POC gaging stations in Walnut Creek and Woman Creek were evaluated for winter freeze protection including outfitting with submersible heat tape to reduce the possibility of sample intake line freezing and the resulting gaps in sample collection. Freezing in sample lines has historically challenged continuous flow-paced sampling during extreme cold weather.

To date, permanent freeze protection has been installed at POC gaging stations GS03 and GS11. This freeze protection consists of AC heat tape, a conductive wrap, and foam insulation along the entire length of the sample intake line. No composite grab samples have been missed at either GS03 or GS11 since installation of freeze protection equipment.

11.3. SOIL AND SEDIMENT SAMPLING

11.3.1. New Locations Tributary to GS03, GS10, and SW093

Additional soil and/or sediment samples may be collected from the drainages tributary to GS03, GS10, and SW093. Locations and numbers of these samples will be determined based on the results of the ongoing Source Evaluations, specifically, based on the incorporation of data from the increased monitoring scope (Source Location monitoring stations). Particular attention will be given to the results of the loading analysis for existing RFCA and Source Location stations. These additional sediment/soil sampling locations will be sited to indicate spatial activity variations and to fill any gaps in existing data. Sediment/soil activities from the drainage pathways tributary to GS03, GS10, and SW093 will be analyzed for spatial variability which may indicate the location of a source area. Summary statistics for these new values will be evaluated against historical results in the area to indicate changes. Additionally, these values will be compared to surface-water radionuclide activities in a loading context.

11.4. ACTINIDE MIGRATION STUDIES

The purpose of the Source Evaluation for Walnut Creek is to provide supplemental monitoring and applied data interpretations. The purpose of the AMS, alternately, is investigation of transuranic migration pathway research with the implementation of longer-term technical studies and the application of results to remedial actions. Regardless, the two projects will synthesize information to increase understanding of the transport of radionuclides in surface water.

The AMS at the Site are being implemented to investigate the mobility of Pu, Am, and U in the Site environment. The general goal of the AMS is to determine how actinides move. Specifically, the goal of the AMS is to address the following questions in the order of priority indicated:

1. Urgent: What are the important actinide migration sources and migration processes that account for recent surface water-quality standard exceedances?

2. Near Term: What will be the impacts of actinide migration on planned remedial actions? To what level do sources need to be remediated to protect surface water from exceeding action levels for actinides?

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3. Long Term: How will actinide migration affect surface-water quality after Site closure? In other words, will soil action levels be sufficiently protective of surface water over the long term?

4. Long Term: What are the prospects for long term, off-site actinide migration, and how will it impact downstream areas (e.g. through accumulation)?

These questions will be addressed by modeling actinide-transport processes to predict actinide loads attributable to known sources of actinides in the Site environment. The EPA DQO process was used as a foundation for establishing the necessary quality of input data for mathematical actinide mobility models (EPA QA/G-4 (1994) and EPA/540/G-93/071 (1993)). The models will be used to estimate the quantity of actinide transported to surface water via each environmental pathway.

The AMS investigations cover the following pathways:

- Runoff/Diffuse Overland Flow,
- Surface Water Flow (Channeled),
- Groundwater Transport - both saturated and unsaturated,
- Interflow (i.e. near surface, saturated flow), and
- Airborne Transport.

For FY98, the AMS scope focuses on the goal of the RFCA and AMS to protect surface water quality and includes the activities shown in Table 11-2.

Investigation of the airborne transport pathway is equally important and study is reserved for FY99 AMS activities. Preliminary findings and plans of the AMS investigations are communicated to stakeholders at public meetings, the most recent of which was held on March 4, 1998.

The AMS investigation that potentially holds the most value for understanding the Walnut Creek exceedances is the erosion and sediment transport modeling. The Site has selected the U.S. Department of Agriculture's Watershed Erosion Prediction Project (WEPP) Model, which will be used to estimate Site soil erosion and associated actinide transport. The Site WEPP model is being utilized in two phases in FY98 and FY99. In FY98, the South Interceptor Ditch and the Walnut Creek drainages will be modeled, and Woman Creek modeling is planned for FY99. Soil actinide data collected in FY98 combined with other radiochemical and hydrologic data from previous studies will be used in conjunction with the WEPP Model output to *estimate* the amounts of Pu, Am, and U expected to be mobilized and potentially available to be transported off Site given present and expected future Site conditions.

Table 11-2. Summary of FY98 AMS Activities.

Description of Activities	Principal Investigator(s)	Status
Plutonium Speciation, Solubilization, and Migration in Soil and Sediment	Mary Neu, Wolfgang Runde, *Los Alamos National Laboratory*	In Progress
Actinide Phase (e.g. form) and Particle Size Distribution	Bruce Honeyman, *Colorado School of Mines* Peter Santschi, *Texas A&M University*	In Progress
Actinide Loading Analysis (Surface Water)	Greg Wetherbee, *Wright Water Engineers, Inc.*	Completed, In Review
Soil Erosion and Surface Water Sediment Transport Modeling	Win Chromec, *RMRS, L.L.C.*	In Progress
Groundwater Geochemical Modeling	Jim Ball, U. S. Geological Survey	In Progress

The AMS Actinide Loading Analysis is now complete and in review. The loading analysis will be used to calibrate the WEPP Model to actual conditions. The loading analysis provides estimated actinide yields (i.e. mass quantities moved) observed for individual storm events and extrapolations of the observed data to estimations of annual yields.

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12. SUMMARY AND CONCLUSIONS

Rocky Flats Environmental Technology Site personnel have completed their initial investigation of, and are continuing the source evaluation for potential cause(s) of exceedances of 30-day moving averages for plutonium (Pu) and americium (Am) water-quality standards at the Walnut Creek RFCA Point of Compliance monitoring location, GS03 and two upstream Point of Evaluation monitoring locations, GS10, and SW093. Site personnel completed an extensive evaluation of historical data; collected additional field soil, sediment, and water samples for analyses; and assessed Site activities and monitoring programs. To date, no localized areas of radiological contamination have been identified—either historical or resulting from current operations – that could have caused this exceedance. Site personnel conclude that the likely source of the exceedances of the 30-day average for Pu and Am, in particular at Point of Compliance GS03, was diffuse radionuclide contamination from past Site operations released to the environment through events and conditions over past years. Based on the evaluation, Site personnel believe that no specific remedial action(s) is indicated at this time as the source investigations have identified no localized source(s) of contamination.

Site personnel are continuing a surface-water source investigation using both in-house and outside expertise, as well as state-of-the-art research methods and technologies. Enhancements in monitoring activities and administrative processes have been implemented to provide early indications and improved resolution of any future water-quality excursions, and to continue to investigate the causes of elevated Pu levels at GS03 (in 1997) and at upstream evaluation locations.

This Final Report contains no specific recommendations for source control due to the exceedance that was measured at GS03. The recommended course of action in this report will not compromise protection of human health and the environment since: (1) the plutonium and americium released from the Site which caused the exceedance, aggregated with the volume-weighted activity for the Water Year, is well below the annualized mass loading used to develop the POC Standard value of 0.15 pCi/l Pu and Am, and (2) there is no consumptive use of the RFETS water that is discharged due to Option B changes in Walnut Creek.[30]

The Site's proposed course of action includes (1) continuing observation (routine monitoring and special sampling, of the surface water as appropriate), and (2) continuing progress on the actinide migration study. Effective best management practices, such as the use of the existing terminal ponds to clarify stormwater of potentially contaminated sediment and particulate matter, should be continued. Specifically, the Site proposes the following actions as the path forward:

- Continued observation (routine monitoring and special sampling, as appropriate to the evaluation) and ongoing data interpretation to provide better understanding of actinide transport directly related to the

[30] Implementation of Option B in Walnut Creek included the purchase of a new water supply and construction of a new water treatment facility for the City of Broomfield.

operation of the Site automated surface-water monitoring network. This monitoring and the associated evaluations will be invaluable should an exceedance occur in the future.

- Continued progress on the AMS as a longer-term technical study to provide understanding of transuranic migration to eventually provide insights about the cause(s) and possible prevention of radionuclide water-quality exceedances. This multi-disciplinary study and the associated watershed modeling initiative is key to understanding water quality variation on the Site, and will eventually describe the extent, and conditions under which plutonium and americium move in the Rocky Flats environs. Site personnel expect these efforts will provide insights about the cause(s) and possible prevention of radionuclide water-quality exceedances.

- Continued use of the existing detention ponds to clarify stormwater of potentially contaminated sediment and particulate matter as an effective best management practice.

- Incorporate direct and increased stakeholder participation in the formulation of mitigating responses to these exceedances through the formation of a Surface-Water Issues Working Group as outlined in Appendix 5 of RFCA; and,

- Provide progress reporting through AMS reports, Quarterly RFCA Reports, Quarterly State Exchange Meetings, and informal status/flash briefs. This will include soil sampling data and analysis not included in this Final Report to the Source Evaluation and Mitigating Actions Plan for Walnut Creek.

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Appendix A : DATA TABLES

Table A-1. Summary of Terminal Pond Discharges for April 3, 1997 through March 31, 1998.

Location	Discharge Dates	Volume Discharged (gal)
Pond A-4	4/3/97 - 4/13/97	13,609,000
Pond B-5	4/28/97 - 5/12/97	15,450,000
Pond A-4	5/1/97 - 5/14/97	25,616,000
Pond A-4	6/25/97 - 7/6/97	13,319,000
Pond A-4	8/5/97 - 8/7/97	4,250,000
Pond A-4	8/29/97 - 9/8/97	17,916,000
Pond B-5	9/24/97 - 10/10/97	12,006,000
Pond A-4	10/1/97 - 10/10/97	9,606,000
Pond A-4	11/21/97 - 12/5/97	36,299,000
Pond A-4	2/12/98 - 2/23/98	16,525,000

Table A-2. Composite Sample Analytical Results for GS11: April 8 through October 10, 1997.

Composite Sample Period	Pu-239,240 (pCi/l)		Am-241 (pCi/l)		Composite Sample Volume (Liters)	Pond A-4 Discharge Volume During Sample Period (Million Gallons)
	Result	Error	Result	Error		
4/8 - 4/13/97	0.001	±0.005	0.008	±0.012	8.2	4.98
5/1 - 5/6/97	0.006	±0.004	0.005	±0.007	17.4	14.61
5/6 - 5/8/97	0.006	±0.005	0.002	±0.006	6.8	3.85
5/8 - 5/14/97	0.006	±0.004	0.003	±0.005	10.6	7.16
6/25 - 6/27/97	0.002	±0.005	0.009	±0.011	9.4	3.42
6/27 - 7/1/97	0.000[a]	±0.012	0.004	±0.017	4.0	5.67
7/1 - 7/6/97	0.003	±0.012	0.009	±0.012	7.8	4.22
8/5 - 8/7/97	0.000[b]	±0.008	0.000	±0.013	13.8	4.25
8/29 - 9/1/97	0.032	±0.003	0.005	±0.006	10.6	6.62
9/1 - 9/4/97	0.054	±0.000	0.008	±0.006	11.2	5.78
9/4 - 9/8/97	0.027	±0.003	0.006	±0.008	10.8	5.51
10/1 - 10/5/97	0.006	±0.008	0.002	±0.007	10.6	4.04
10/5 - 10/8/97	0.005	±0.009	0.002	±0.021	11.4	3.75
10/8 - 10/10/97	0.000[c]	±0.012	0.000[d]	±0.017	6.4	1.81
11/21 - 11/24/97	0.006	±0.015	0.000[e]	±0.019	9.8	10.14
11/24 - 11/28/97[f]	0.000[g]	±0.0085	0.0045	±0.022	10.6	9.94
11/28 - 12/5/97	0.009	±0.013	0.003	±0.017	14.4	16.22

[a] Actual result was -0.009 pCi/l for this sample; negative results are set to zero for practical reporting and calculation purposes.
[b] Actual result was -0.008 pCi/l for this sample.
[c] Actual result was -0.003 pCi/l for this sample.
[d] Actual result was -0.001 pCi/l for this sample.
[e] Actual result was -0.002 pCi/l for this sample.
[f] This sample had a duplicate; reported values are arithmetic averages.
[g] Actual results were -0.001 and -0.006 pCi/l for this sample.

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Table A-3. Composite Sample Analytical Results for GS08: April 8 through January 19, 1998.

Composite Sample Period	Pu-239,240 (pCi/l)		Am-241 (pCi/l)		Composite Sample Volume (Liters)	Pond B-5 Discharge Volume During Sample Period (Million Gallons)
	Result	Error	Result	Error		
4/28 - 5/1/97	0.017	±0.006	0.013	±0.016	12.6	5.38
5/1 - 5/6/97	0.006	±0.003	0.000	±0.011	5.8	4.92
5/6 - 5/12/97	0.008	±0.004	0.005	±0.005	13.2	5.15
9/24 - 9/26/97	0.001	±0.010	0.022	±0.024	6.8	2.49
9/26 - 9/30/97	0.000[a]	±0.006	0.006	±0.007	11.8	4.97
9/30 - 10/10/97	0.000[b]	±0.010	0.010	±0.023	10.6	4.54
1/19/98[c]	0.006	±0.012	0.005	±0.026	15.0	0.006

[a] Actual result was -0.001 pCi/l for this sample; negative results are set to zero for practical reporting and calculation purposes.
[b] Actual result was -0.003 pCi/l for this sample.
[c] Sample collected from water used to pressure test B-5 outlet works upgrades.

Table A-4. Composite Sample Analytical Results for GS10: March 28 through October 22, 1997.

Composite Sample Period	Pu-239,240 (pCi/l)		Am-241 (pCi/l)		Composite Sample Volume (Liters)	S. Walnut Cr. Discharge Volume During Sample Period (Million Gallons)
	Result	Error	Result	Error		
3/28 - 4/2/97	0.300	±0.026	0.140	±0.015	6.0	0.29
4/2 - 4/11/97	0.150	±0.017	0.110	±0.021	8.8	1.37
4/11 - 4/24/97	0.410	±0.041	0.140	±0.019	12.2	2.45
4/24 - 4/25/97	0.086	±0.014	0.045	±0.009	12.8	1.60
4/25 - 4/26/97	0.070	±0.012	0.033	±0.009	11.0	2.41
4/26 - 5/12/97	0.086	±0.014	0.120	±0.017	4.0	2.70
5/12 - 5/25/97	0.380	±0.049	0.300	±0.044	7.4	1.19
5/25 - 6/8/97	0.134	±0.043	0.106	±0.053	9.6	1.66
6/8 - 6/12/97	0.056	±0.027	0.052	±0.032	6.0	0.32
6/12 - 6/16/97	0.088	±0.030	0.077	±0.036	8.8	0.46
6/16 - 6/23/97	0.005	±0.010	0.048	±0.033	7.2	0.36
6/23 - 6/30/97	0.274	±0.073	0.100	±0.051	6.6	0.36
6/30 - 7/8/97	0.056	±0.036	0.061	±0.048	9.4	0.35
7/8 - 7/16/97	0.028	±0.020	0.032	±0.023	11.8	0.42
7/16 - 7/23/97	0.026	±0.025	0.043	±0.026	11.2	0.41
7/23 - 7/31/97	0.107	±0.047	0.075	±0.054	15.2	1.97
7/31 - 8/4/97	1.460	±0.197	0.497	±0.173	11.2	1.19
8/4 - 8/6/97	1.910	±0.256	2.210	±0.382	15.4	2.24
8/6 - 9/1/97	0.070	±0.002	0.468	±0.006	15.0	3.42
9/1 - 9/18/97	0.077	±0.034	0.130	±0.080	10.2	0.76
9/18 - 9/23/97	0.427	±0.072	0.687	±0.151	15.0	1.72
9/23 - 10/2/97	0.104	±0.024	0.097	±0.022	7.0	0.53
10/2 - 10/8/97	0.000[a]	±0.011	0.014	±0.023	9.2	0.41
10/8 - 10/13/97	0.040	±0.050	0.035	±0.029	14.2	0.50
10/13 - 10/22/97	0.000[b]	±0.008	0.023	±0.023	12.6	0.45

[a] Result was -0.003
[b] Result was -0.010

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Table A-5. Composite Sample Analytical Results for SW093: July 21 through October 6, 1997.

Composite Sample Period	Pu-239,240 (pCi/l)		Am-241 (pCi/l)		Composite Sample Volume (Liters)	N. Walnut Cr. Discharge Volume During Sample Period (Million Gallons)
	Result	Error	Result	Error		
7/21 - 7/29/97	0.208	±0.063	0.037	±0.074	10.2	0.46
7/29 - 7/30/97	0.224	±0.063	0.247	±0.087	13.4	0.78
7/30 - 8/1/97	0.037	±0.025	0.026	±0.034	8.0	0.39
8/1 - 8/4/97	1.330	±0.213	0.628	±0.166	12.8	1.18
8/4 - 8/6/97	0.085	±0.035	0.044	±0.037	15.0	2.70
8/6 - 8/12/97	0.020	±0.200	0.036	±0.201	13.0	2.81
8/12 - 9/1/97	0.002	±0.005	0.016	±0.005	8.4	1.89
9/1 - 9/18/97	0.002	±0.009	0.000	±0.014	12.4	0.79
9/18 - 9/23/97	0.018	±0.016	0.033	±0.028	15.0	1.66
9/23 - 10/6/97	0.000[a]	±0.002	0.005	±0.017	6.0	0.86

[a] Actual result was -0.003 pCi/l for this sample; negative results are set to zero for practical reporting and calculation purposes.

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Table A-6. Sample Detail for GS03: Walnut Creek at Indiana Street.

Sample Start Time	Sample End Time	Discharge Volume During Sample (cubic feet)	Pu-239, 240 Activity (pCi/l)	Pu-239, 240 Load (micrograms)
10/1/96 0:00[a]	None	1481303	*0.032*	18.81
10/14/96 14:38	12/20/96 12:16	69687	0.015	0.42
12/20/96 12:16	12/23/96 11:39	610219	0.003	0.73
12/23/96 11:39	12/26/96 12:13	440743	0.006	1.05
12/26/96 12:13	12/30/96 14:32	124911	0.001	0.05
2/20/97 14:21	2/22/97 15:39	609170	0.017	4.13
2/22/97 15:39	3/3/97 11:08	1101256	0.025	10.98
3/3/97 11:08	4/3; NSQ[b]	9699	*0.032*	0.12
4/3/97 12:47	4/5/97 16:37	470746	0.022	4.13
4/5/97 16:37	4/8/97 17:12	624135	0.007	1.74
4/8/97 17:12	**4/15/97 11:16**	709435	**0.220**	62.26
4/15/97 11:16	4/26/97 16:28	1265362	0.018	9.09
4/26/97 16:28	4/28/97 13:57	2054116	0.036	29.50
4/28/97 13:57	5/1/97 16:25	1010904	0.005	2.02
5/1/97 16:25	5/3/97 14:07	1139103	0.016	7.27
5/3/97 14:07	5/6/97 12:04	1479879	0.021	12.40
5/6/97 12:04	5/7/97 13:16	442806	0.013	2.30
5/7/97 13:16	5/9/97 14:50	692467	0.005	1.38
5/9/97 14:50	5/15/97 7:40	1077900	0.027	11.39
5/15/97 7:40	**6/25/97 15:15**	45743	**0.465**	8.48
6/25/97 15:15	**6/27/97 13:35**	378015	**0.165**	24.88
6/27/97 13:35	**7/1/97 14:07**	719360	**0.184**	52.80
7/1/97 14:07	7/6/97 17:14	547709	0.000	0.00
7/6/97 17:14	8/5; NSQ[b]	13939	*0.032*	0.18
8/5/97 14:24	8/8/97 7:57	724257	0.002	0.58
8/8/97 7:57	8/29/97 12:55	47023	0.028	0.53
8/29/97 12:55	9/1/97 10:17	760556	0.023	6.98
9/1/97 10:17	9/4/97 10:42	752023	0.000	0.00
9/4/97 10:42	9/9/97 10:51	699115	0.009	2.51
9/9/97 10:51	9/24/97 17:15	23860	0.019	0.18
9/24/97 17:15	9/27/97 22:39	395717	0.004	0.63
9/27/97 22:39	10/1/97 15:58	572984	0.000	0.00
10/1/97 15:58	10/3/97 14:07	525014	0.000	0.00
10/3/97 14:07	10/5/97 13:42	292123	0.000	0.00
10/5/97 13:42	10/8/97 11:01	545216	0.008	1.74
10/8/97 11:01	10/10/97 16:16	283858	0.000	0.00
10/10/97 16:16	10/27/97 9:39	79270	0.014	0.44
10/27/97 9:39	10/30/97 15:39	324366	0.002	0.26
10/30/97 15:40	11/21/97 11:02	557366	0.000	0.00
11/21/97 11:02	11/24/97 14:16	1282406	0.014	7.16
11/24/97 14:16	11/28/97 17:11	1312111	0.000	0.00
11/28/97 17:11	12/5/97 14:59	2098925	0.004	3.35

[a] Sampling began on 10/14/96, after the completion of a B-5 discharge started in FY96, activity set to WY97 volume-weighted average for loading calculation purposes.
[b] Sample had insufficient volume for analysis, activity set to WY97 volume-weighted average for loading calculation purposes.
Elevated samples are indicated in bold.

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Table A-7. Sample Detail for GS08: Pond B-5 Outlet.

Sample Start Time	Sample End Time	Discharge Volume During Sample (cubic feet)	Pu-239, 240 Activity (pCi/l)	Pu-239, 240 Load (micrograms)
10/1/96 0:00[a]	10/10/96 10:15	1535344	*0.007*	4.18
4/28/97 12:02	5/1/97 10:08	718814	0.017	4.87
5/1/97 10:08	5/6/97 14:51	658154	0.006	1.58
5/6/97 14:51	5/12/97 14:33	688436	0.008	2.20
9/24/97 14:28	9/26/97 15:10	333079	0.001	0.13
9/26/97 15:10	9/30/97 14:29	664923	0.000	0.00
9/30/97 14:29	10/10/97 13:30	606987	0.000	0.00

[a] B-5 discharge started in FY96 was not sampled, activity set to volume-weighted average to date for loading calculation purposes.

Table A-8. Sample Detail for GS11: Pond A-4 Outlet.

Sample Start Time	Sample End Time	Discharge Volume During Sample (cubic feet)	Pu-239, 240 Activity (pCi/l)	Pu-239, 240 Load (micrograms)
12/20/96 8:05	12/23/96 8:58	705648	0.001	0.28
12/23/96 8:58	12/26/96 9:07	462124	0.002	0.37
12/26/96 9:07	12/28/96 7:17	105866	0.001	0.04
2/20/97 10:01	2/22/97 13:42	675876	0.003	0.81
2/22/97 13:42	2/25/97 13:52	685803	0.000	0.00
2/25/97 13:52	3/2/97 14:48	395895	0.001	0.16
4/3/97 10:08	4/5/97 16:12	552740	0.004	0.88
4/5/97 16:12	4/8/97 14:31	592151	0.000	0.00
4/8/97 14:31	4/13/97 11:11	665231	0.001	0.27
5/1/97 15:26	5/6/97 13:53	1952671	0.006	4.67
5/6/97 13:53	5/8/97 12:14	514592	0.006	1.23
5/8/97 12:14	5/14/97 11:46	957148	0.006	2.29
6/25/97 13:44	6/27/97 13:15	457604	0.002	0.37
6/27/97 13:15	7/1/97 13:49	758314	0.000	0.00
7/1/97 13:49	7/6/97 8:19	564141	0.003	0.68
8/5/97 11:15	8/7/97 15:14	568103	0.000	0.00
8/29/97 10:02	9/1/97 9:32	885503	0.032	11.30
9/1/97 9:32	9/4/97 10:04	772769	0.054	16.65
9/4/97 10:04	9/8/97 9:45	736736	0.027	7.79
10/1/97 14:13	10/5/97 13:13	540656	0.006	1.29
10/5/97 13:13	10/8/97 10:34	501448	0.005	1.00
10/8/97 10:34	10/10/97 10:45	242083	0.000	0.00
11/21/97 9:13	11/24/97 12:43	1355547	0.006	3.24
11/24/97 12:43	11/28/97 13:47	1328751	0.000	0.00
11/28/97 13:47	12/5/97 11:45	2168233	0.009	7.78

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Table A-9. Preliminary Pu-239,240 and Am-241 activity data for Walnut Creek Watershed Soils.

Locations	Am-241 Result (pCi/g)	Am-241 Error (pCi/g)	Pu-239,240 Result (pCi/g)	Pu-239,240 Error (pCi/g)
SSSE00198	0.532	±0.087	1.990	±0.423
SSSE00298	0.675	±0.096	RERUN	RERUN
SSSE00398	0.312	±0.074	1.400	±0.303
SSSE00498	0.254	±0.050	RERUN	RERUN
SSSE00598	0.072	±0.036	0.465	±0.212
SSSE00698	0.099	±0.041	RERUN	RERUN
SSSE00798	0.038	±0.047	0.205	±0.138
SSSE00898	-0.006	±0.084	0.048	±0.084
SSSE00998	0.050	±0.042	0.143	±0.112
SSSE01098	RERUN	RERUN	0.084	±0.082
SSSE01198	0.045	±0.030	0.247	±0.160
SSSE01298	0.141	±0.046	0.753	±0.257
SSSE01398	0.034	±0.049	0.240	±0.092
SSSE01498	0.011	±0.046	0.207	±0.074
SSSE01498	0.064	±0.031	0.241	±0.136
SSSE01598	0.042	±0.047	RERUN	RERUN
SSSE01698	0.037	±0.046	0.068	±0.108
SSSE01798	0.272	±0.074	0.530	±0.170
SSSE01898	0.037	±0.026	0.103	±0.077
SSSE01998	0.034	±0.031	0.151	±0.112
SSSE02098	-0.014	±0.036	0.008	±0.099
SSSE02198	0.038	±0.031	0.070	±0.083
SSSE02298	0.025	±0.032	-0.011	±0.015
SSSE02398	0.043	±0.051	0.060	±0.120
SSSE02498	0.037	±0.041	0.008	±0.045
SSSE02598	RERUN	RERUN	RERUN	RERUN
SSSE02698	0.027	±0.038	0.061	±0.049
SSSE02798	0.030	±0.038	0.057	±0.056
SSSE02898	0.009	±0.036	0.115	±0.110
SSSE02998	0.058	±0.050	0.029	±0.047
SSSE03098	-0.011	±0.034	0.063	±0.059
SSSE03198	0.016	±0.026	RERUN	RERUN
SSSE03298	0.010	±0.033	0.086	±0.055
SSSE03398	0.035	±0.035	0.010	±0.093

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Table A-10. Detail for WY97 - WY98 Continuous Flow-Paced Composite Samples at GS10.

Sample Start Time	Sample End Time	Discharge Volume During Sample (ft^3)	Pu-239, 240 Activity (pCi/l)	Pu-239, 240 Load (micrograms)
10/1/96 11:24	10/16/96 13:51	68375[a]	0.032	0.87
10/16/96 13:51	10/31/96 9:13	93846	0.077	2.88
10/31/96 9:13	11/11/96 23:57	49095	0.0295	0.58
11/11/96 23:57	11/20/96 15:13	74221	0.037	1.10
11/20/96 15:13	12/3/96 15:52	79418	0.057	1.81
12/3/96 15:52	12/20/96 15:15	67745	0.064	1.73
12/20/96 15:15	1/3/97 14:25	61756	0.027	0.67
1/3/97 14:25	2/5/97 16:37	152467	0.074	4.50
2/5/97 16:37	**2/18/97 14:37**	**63597**	**0.16**	**4.06**
2/18/97 14:37	**2/24/97 15:51**	**84912**	**0.17**	**5.76**
2/24/97 15:51	3/5/97 14:51	87008	0.025	0.87
3/5/97 14:51	3/17/97 11:06	71098	0.054	1.53
3/17/97 11:06	3/28/97 9:13	86086	0.12	4.12
3/28/97 9:13	**4/2/97 16:10**	**38549**	**0.3**	**4.61**
4/2/97 16:10	**4/11/97 13:56**	**182496**	**0.15**	**10.92**
4/11/97 13:56	**4/24/97 8:56**	**328065**	**0.41**	**53.65**
4/24/97 8:56	4/25/97 12:59	213488	0.086	7.32
4/25/97 12:59	4/26/97 17:02	321887	0.07	8.99
4/26/97 17:02	5/12/97 16:01	360457	0.086	12.37
5/12/97 16:01	**5/25/97 15:48**	**158561**	**0.38**	**24.03**
5/25/97 15:48	6/8/97 13:53	221434	0.134	11.84
6/8/97 13:53	6/12/97 10:05	42200	0.056	0.94
6/12/97 10:05	6/16/97 8:06	61625	0.088	2.16
6/16/97 8:06	6/23/97 7:35	47979	0.005	0.10
6/23/97 7:35	**6/30/97 13:24**	**48441**	**0.274**	**5.29**
6/30/97 13:24	7/8/97 7:49	46557	0.056	1.04
7/8/97 7:49	7/16/97 15:24	56555	0.028	0.63
7/16/97 15:24	7/23/97 15:41	55268	0.026	0.57
7/23/97 15:41	7/31/97 9:09	263898	0.107	11.26
7/31/97 9:09	**8/4/97 17:25**	**158668**	**1.46**	**92.40**
8/4/97 17:25	**8/6/97 7:55**	**300046**	**1.91**	**228.60**
8/6/97 7:55	9/1/97 9:14	457693	0.07	12.78
9/1/97 9:14	9/18/97 10:27	101433	0.077	3.12
9/18/97 10:27	**9/23/97 16:55**	**230406**	**0.427**	**39.24**
9/23/97 16:55	10/2/97 11:44	71022	0.104	2.95
10/2/97 11:44	10/8/97 10:13	55182	0.000[b]	0.00
10/8/97 10:13	10/13/97 7:56	67446	0.040	1.08
10/13/97 7:56	10/22/97 14:20	60500	0.000[b]	0.00
10/22/97 14:20	10/24/97 15:45	50575	0.062	1.25
10/24/97 15:45	10/29/97 14:39	347352	0.035	4.85
10/29/97 14:39	11/7/97 16:29	128263	0.014	0.72
11/7/97 16:29	11/13/97 14:45	108332	0.070	3.02
11/13/97 14:45	12/1/97 8:10	177847	0.127	9.01
12/1/97 8:10	12/31/97 14:51	235954	0.012	1.13
12/31/97 14:51	1/28/98 7:08	209671	0.016	1.34

Elevated samples above the action level are indicated in bold.
[a] Discharge volume calculated from 10/1/96 0:00 for loading purposes.
[b] Result was a negative value; set to zero for load calculation purposes.

Locations	Am-241 Result (pCi/g)	Am-241 Error (pCi/g)	Pu-239,240 Result (pCi/g)	Pu-239,240 Error (pCi/g)
SSSE03498	0.010	±0.039	0.017	±0.061
SSSE03598	0.038	±0.040	0.090	±0.110
SSSE03698	0.004	±0.052	0.012	±0.023
SSSE03698	-0.010	±0.049	0.042	±0.041
SSSE03798	0.032	±0.038	0.105	±0.059
SSSE03898	0.013	±0.030	0.027	±0.053
SSSE03998	0.000	±0.040	RERUN	RERUN
SSSE04098	0.020	±0.029	RERUN	RERUN
SSSE04198	0.017	±0.038	0.006	±0.061
SSSE04298	0.032	±0.040	0.015	±0.055
SSSE04398	0.004	±0.038	RERUN	RERUN
SSSE04498	0.041	±0.032	0.048	±0.050
SSSE04598	RERUN	RERUN	0.055	±0.053
SSSE04698	0.029	±0.041	0.091	±0.060
SSSE04798	0.031	±0.035	0.055	±0.070
SSSE04898	0.007	±0.024	0.106	±0.109
SSSE04998	0.042	±0.038	RERUN	RERUN
SSSE05098	0.082	±0.039	0.512	±0.136
SSSE05198	0.252	±0.064	1.320	±0.200

	Am-241	Am-241 Error	Pu-239,240	Pu-239,240 Error
Average	0.074	±0.043	0.231	±0.105
Minimum	-0.014	±0.024	-0.011	±0.015
Maximum	0.675	±0.096	1.990	±0.423

Notes: 1) Data are preliminary and subject to revision. 2) RERUN = Analysis will be rerun due to quality assurance requirements. 3) DUP = Field duplicate sample.

Table A-11. Detail for WY97 - WY98 Flow-Paced Storm-Event Composite Samples at SW022, GS27, and GS28.

Location	Sample Date	Pu-239, 240 Activity (pCi/l)
SW022	10/26/96	0.029
	2/18/97	0.087
	4/2/97	0.082
	4/4/97	0.230
	4/23/97	0.060
	5/22/97	0.019
	6/6/97	0.030
	7/28/97	0.357
	7/30/97	1.180
	8/4/97	6.000
	10/12/97	0.010
GS27		
	4/2/97	0.870
	4/4/97	3.000
	4/23/97	1.900
	5/24/97	3.000
	7/28/97	2.100
	7/30/97	3.170
	8/4/97	6.190
	10/24/97	3.540
	1/17/98	1.130

Table A-12. Detail for WY97 - WY98 Continuous Flow-Paced Composite Samples at SW093.

Sample Start Time	Sample End Time	Discharge Volume During Sample (cubic feet)	Pu-239, 240 Activity (pCi/l)	Pu-239, 240 Load (micrograms)
10/1/96 14:22[a]	10/15/96 22:15	64747	0.091	2.35
10/15/96 22:15	10/24/96 11:19	56718	0.018	0.41
10/24/96 11:19	10/31/96 18:24	61320	0.160	3.91
10/31/96 18:24	11/11/96 22:23	49156	0.077	1.51
11/11/96 22:23	11/19/96 19:06	71967	0.026	0.75
11/19/96 19:06	12/3/96 15:23	89457	0.179	6.39
12/3/96 15:23	12/16/96 13:26	59800	0.002	0.05
12/16/96 13:26	12/30; NSQ[b]	80351	*0.039*	1.25
12/30/96 13:00	1/21/97 10:37	96263	0.004	0.15
1/21/97 10:37	2/3/97 15:29	60558	0.003	0.07
2/3/97 15:29	2/18/97 14:11	76933	0.004	0.12
2/18/97 14:11	2/28/97 14:02	178825	0.033	2.35
2/28/97 14:02	3/10/97 16:13	172866	0.004	0.28
3/10/97 16:13	3/24/97 10:46	104459	0.001	0.04
3/24/97 10:46	3/28/97 10:17	49254	0.008	0.16
3/28/97 10:17	4/2/97 15:43	43413	0.038	0.66
4/2/97 15:43	4/11/97 14:13	243775	0.025	2.43
4/11/97 14:13	4/24/97 9:14	448437	0.042	7.51
4/24/97 9:14	4/25/97 13:16	262160	0.027	2.82
4/25/97 13:16	4/26/97 17:18	409142	0.100	16.32
4/26/97 17:18	5/7/97 11:28	730191	0.015	4.37
5/7/97 11:28	5/25/97 15:39	289800	0.009	1.04
5/25/97 15:39	6/8/97 14:05	251479	0.015	1.50
6/8/97 14:05	6/16/97 8:34	94573	0.044	1.66
6/16/97 8:34	6/24/97 7:56	51675	0.003	0.06
6/24/97 7:56	7/1/97 13:35	29543	0.004	0.05
7/1/97 13:35	7/21/97 15:42	36769	0.001	0.01
7/21/97 15:42	7/29/97 8:35	61095	0.208	5.07
7/29/97 8:35	7/30/97 18:01	104936	0.224	9.38
7/30/97 18:01	8/1/97 14:55	52602	0.037	0.78
8/1/97 14:55	**8/4/97 17:15**	**157997**	**1.330**	**83.82**
8/4/97 17:15	8/6/97 7:39	360821	0.085	12.23
8/6/97 7:39	8/12/97 10:16	375053	0.020	2.99
8/12/97 10:16	9/1/97 9:52	252990	0.002	0.20
9/1/97 9:52	9/18/97 10:15	104940	0.002	0.08
9/18/97 10:15	9/23/97 16:26	222439	0.018	1.60

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Sample Start Time	Sample End Time	Discharge Volume During Sample (cubic feet)	Pu-239, 240 Activity (pCi/l)	Pu-239, 240 Load (micrograms)
9/23/97 16:26[c]	9/30/97 23:59	70496	0.000[d]	0.00
10/1/97 00:00[c]	10/6/97 16:41	37598	0.000[d]	0.00
10/6/97 16:42	10/13/97 16:12	95647	0.005	0.19
10/13/97 16:12	10/23/97 16:33	84538	0.000[d]	0.00
10/23/97 16:33	10/27/97 11:14	286155	0.009	1.03
10/27/97 11:14	11/3/97 15:57	771203	0.004	1.23
11/3/97 15:57	11/7/97 16:39	49532	0.000[d]	0.00
11/7/97 16:39	11/10/97 11:42	80435	0.007	0.22
11/10/97 11:42	11/24/97 13:41	405197	0.006	0.97
11/24/97 13:41	12/1/97 8:39	171286	0.001	0.07
12/1/97 8:39	12/4/97 13:20	79590	0.000[d]	0.00
12/4/97 13:20	12/31/97 15:11	499784	0.000[d]	0.00
12/31/97 15:11	1/14/98 11:20	203527	0.000[d]	0.00
1/14/98 11:20	1/28/98 12:49	201031	0.003	0.24

[a] Discharge volume calculated from 10/1/96 0:00 for loading purposes.
[b] Sample had insufficient volume for analysis, activity set to WY97 volume-weighted average for load calculation purposes.
[c] Samples period divided by water year for annual load calculation purposes.
[d] Negative analytical result set to zero for load calculation purposes.
Elevated samples above the action level are indicated in bold.

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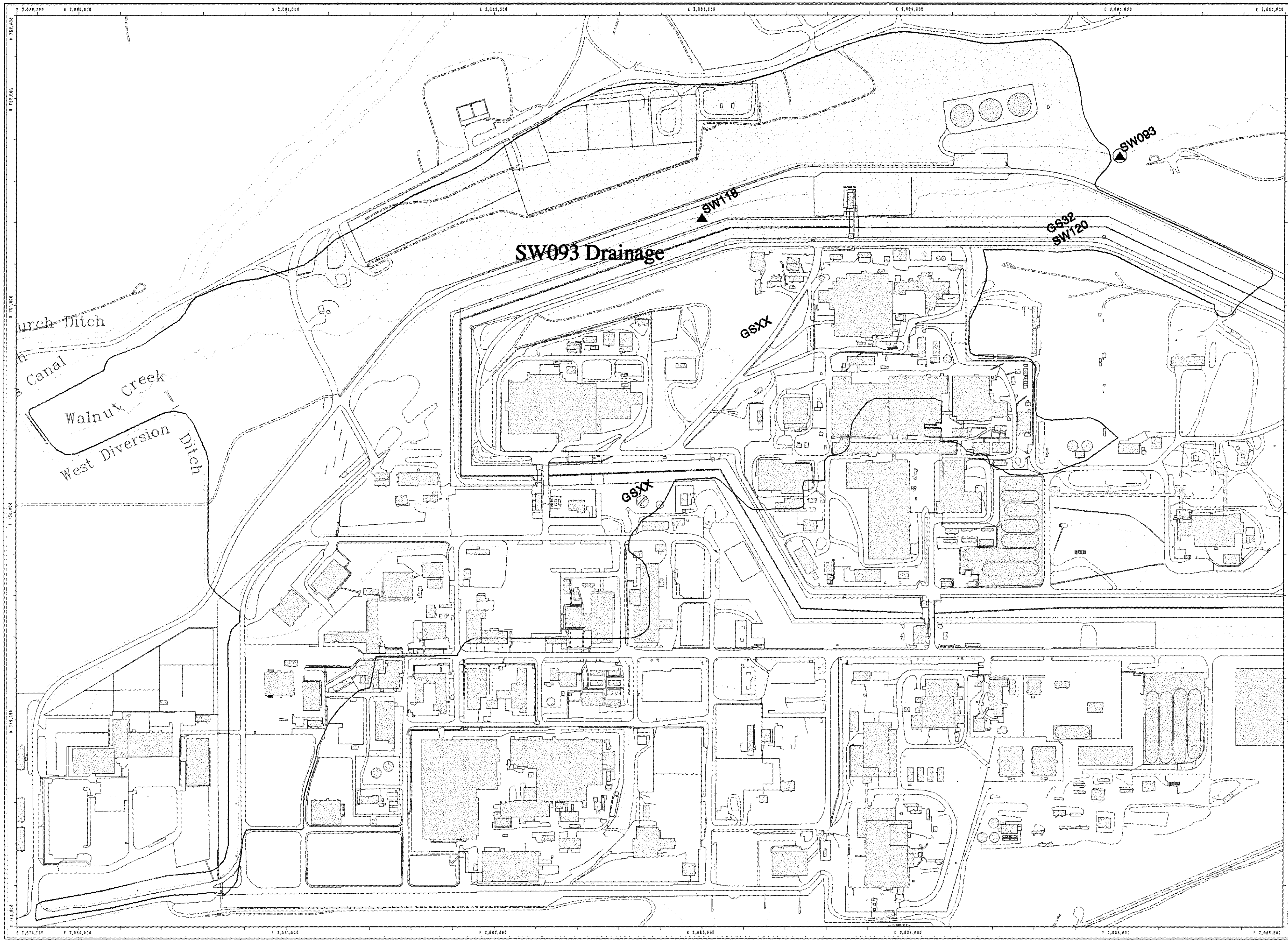

Figure 8-1

Selected Surface-Water Monitoring Locations Tributary to SW093

Legend

Monitoring Locations

- ▲ Point of Evaluation
- Performance
- ▲ Source Location
- Proposed Source Location Station
- ○ New Source Detection

Drainage

- SW093 Drainage

Standard Map Features

- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE: Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the othophotographs. 1/95

Scale = 1 : 6670
1 inch represents approximately 473 feet

100 0 200 400ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by:

RMRS Rocky Mountain Remediation Services, L.L.C.
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Golden, CO 80402-0464

MAP ID: 98-0133-Map4

April 14, 1999

/gis2/projects/fy98/98-0133/map4/sw093-drng.aml

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Figure 2-1

Selected Surface-Water Monitoring Locations in Walnut Creek

Legend

Monitoring Locations
- Point of Compliance
- Point of Evaluation
- Performance
- Source Location
- New Source Detection

Drainages
- GS03 Drainage
- SW093 Drainage
- GS10 Drainage

Standard Map Features
- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE: *Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the othophotographs. 1/95*

Scale = 1 : 9700
1 inch represents approximately 808 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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MAP ID: 98-0133-Map1
April 15, 1998

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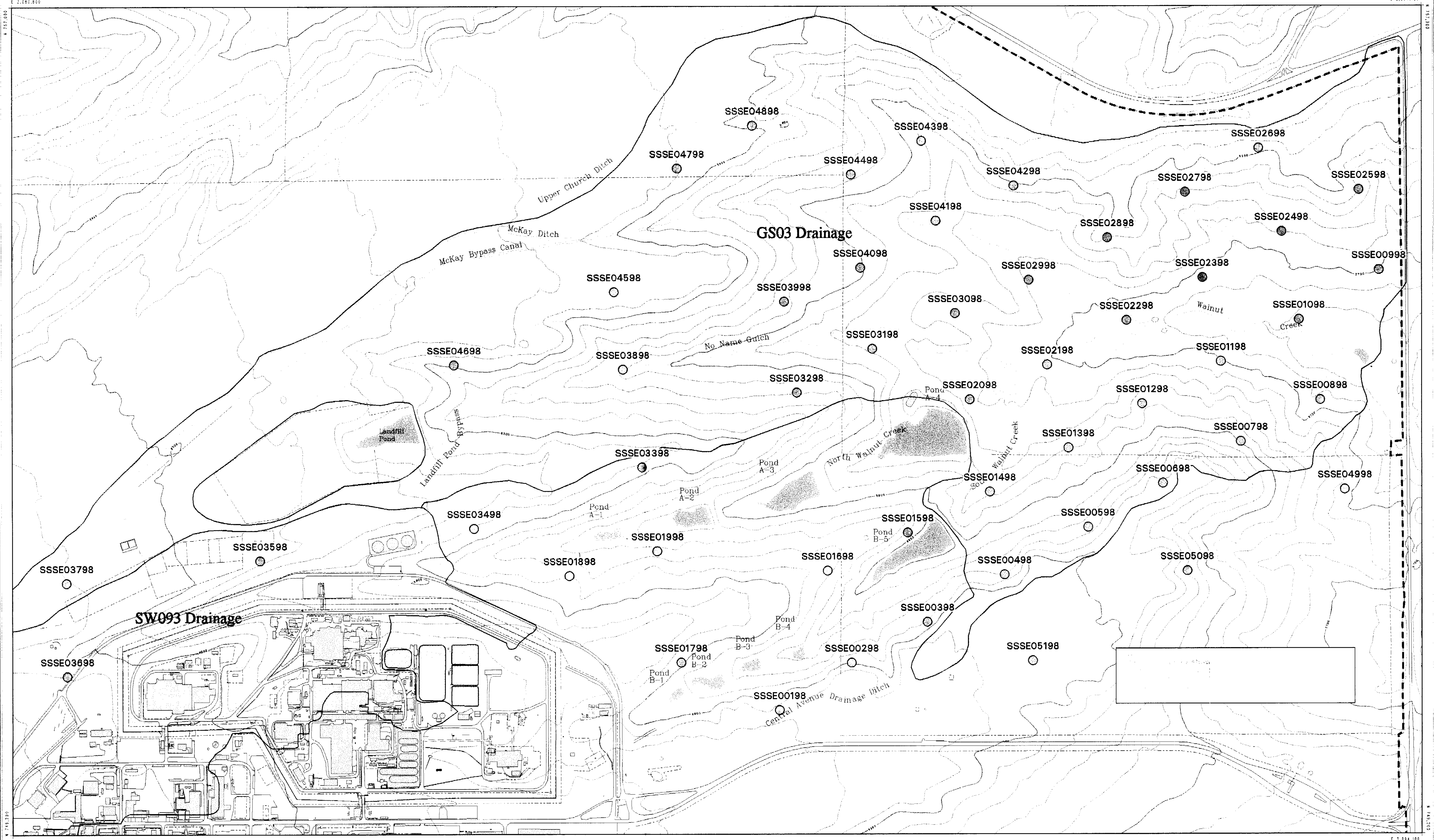

Figure 4-16

New Surface Soil Sampling Locations
in Walnut Creek Drainage Area
(Samples collected Feb-98)

Surface Soil Samples

- Surface Soil Sampling Location
- Sample Fractionated for Radiochemical Analysis by Soil Particle Size

Drainages

- GS03 Drainage
- SW093 Drainage

Standard Map Features

- Buildings and other structures
- Solar evaporation ponds
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Rocky Flats boundary
- Paved roads

DATA SOURCE:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the othophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudson (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours.
The DEM data was capture by the Remote Sensing Lab, Los Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution.
The DEM post-processing perfromed by MK, Winter 1997.

Scale = 1 : 9090
1 inch represents approximately 758 feet

250 0 500 1000ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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Rocky Flats Environmental Technology Site

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MAP ID: 98-0133Map2

April 14, 1998

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44

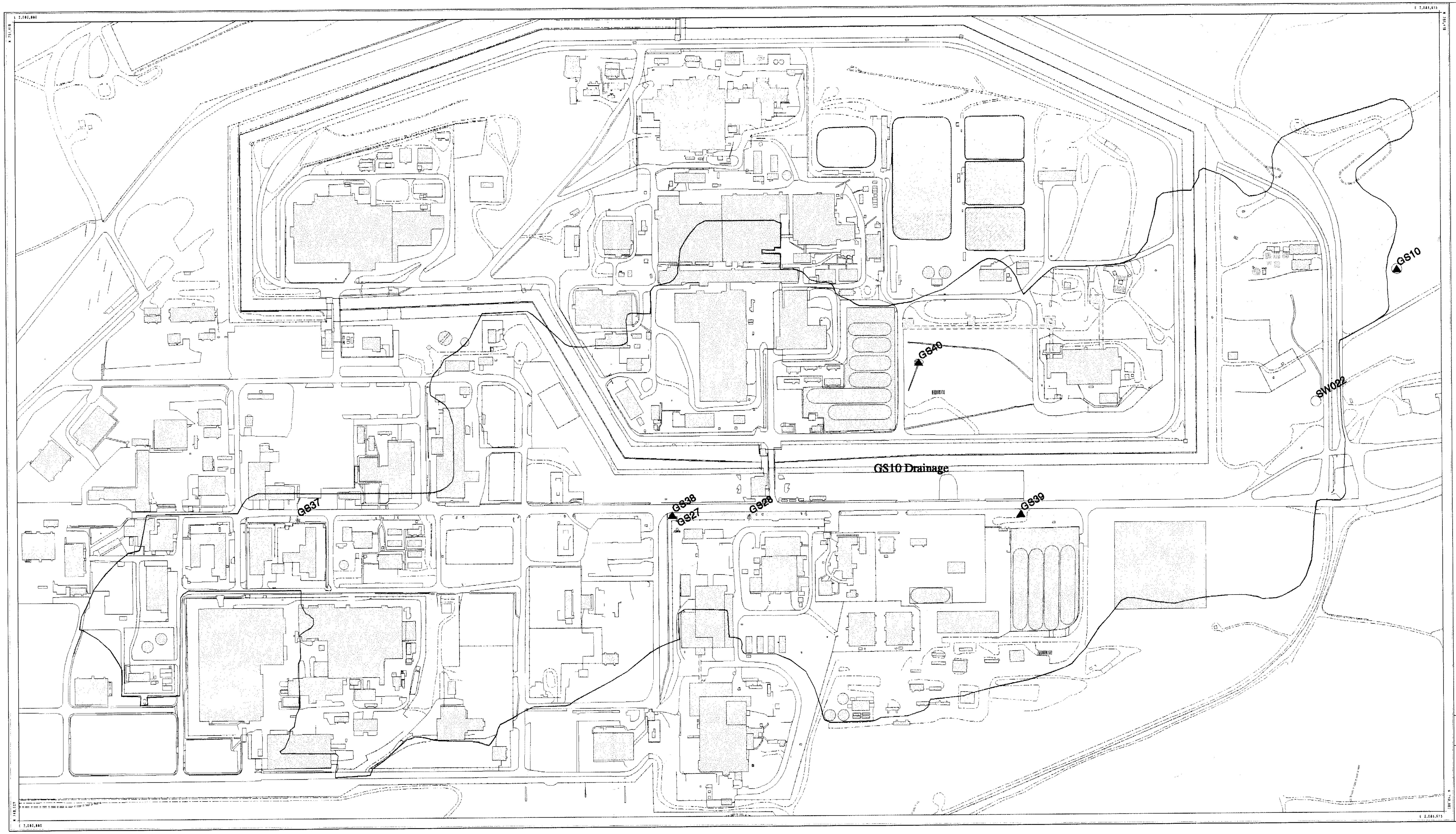

Figure 6-1

Selected Surface Water Monitoring Locations Tributary to GS10

EXPLANATION

Monitoring Locations

- ▲ Point of Evaluation
- Performance
- ▲ Source Location
- ○ New Source Detection

Drainage

- GS10 Drainage

Standard Map Features

- Buildings and other structures
- Solar evaporation ponds
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the othophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudson (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours.
The DEM data was capture by the Remote Sensing Lab, Los Veges, NV, 1994 Aerial Flyover at ~10 meter resolution.
The DEM post-processing perfromed by MK, Winter 1997.

Scale = 1 : 4230
1 inch represents approximately 353 feet

100 0 200 400ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
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MAP ID: 98-0133-Map3

April 13, 1998

/gis2/projects/fy98/98-0133/map3/gs10_loc.aml

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